

# Corrosion

## IN THIS ISSUE:

- Corrosion in a Hydrocarbon  
Conversion System . . . . . 13
- An Industrial Experience of Attack  
On Metals by Synthesis Gas  
From Methane-Oxygen Combustion . . . . 16
- High Temperature Deterioration in  
Atmospheres Containing  
Carbon Monoxide and Hydrogen . . . . . 21
- Corrosion of Metals at  
Mandapam Camp, India . . . . . 25
- Case Histories of Ratings vs Corrosives  
of Polyester Fiber Glass Equipment . . . 29

### INDEX TO VOLUME 15

Tables of Contents Technical and Technical Topics  
Sections; Alphabetical Subject and Author Indexes;  
Subject Index, Vol. 15 Corrosion Abstracts Section;  
Errata, Vol. 15

- Portland, Tulsa, Central Oklahoma  
Section Short Courses Set . . . . . 69, 71
- Characteristic Properties of  
Polyurethane Protective Coatings . . . . . 93
- Corrosion Control Practices in the  
Wilmington Water Flood Operation . . . 99
- Cathodic Protection of Southern Pacific's  
High-Pressure Products Pipe Line . . . . 104

Also: Discussions; Epoxy Resins Resist Gamma Radia-  
tion; New Products, Men in the News, Corrosion  
Abstracts

Complete Contents on Pages 2 and 3



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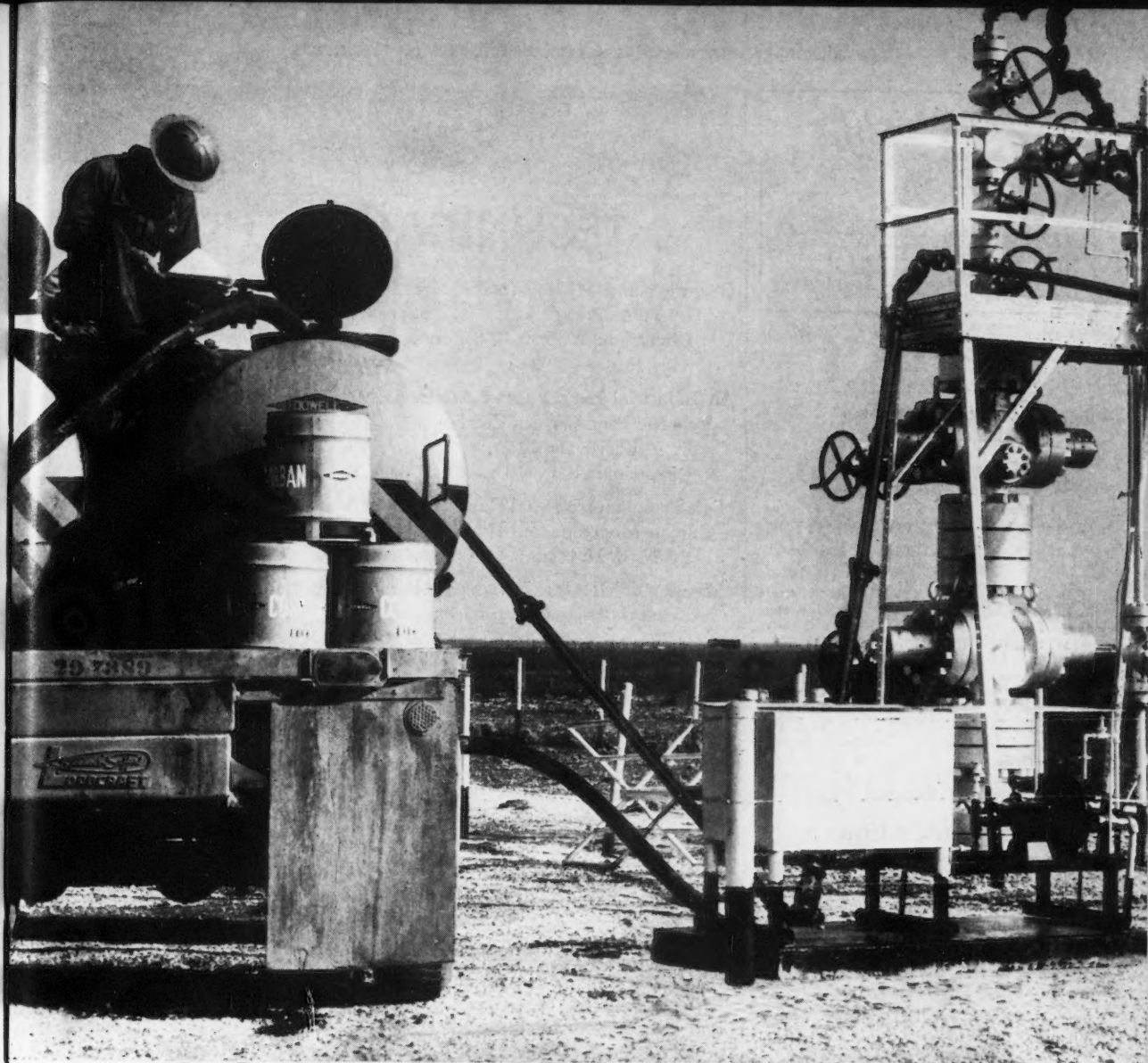
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# CONTENTS

## TECHNICAL SECTION

Corrosion in a Hydrocarbon Conversion System	Page
By F. A. Prange.....	13
Discussion: William B. Segraves, page 15; Reply by F. A. Prange, page 15	
An Industrial Experience of Attack on Metals by Synthesis Gas from Methane-Oxygen Combustion	
By F. Eberle and R. D. Wylie.....	16
Discussion: Andrew Dravnieks, page 20; Reply by F. Eberle, page 20	
High Temperature Metal Deterioration in Atmospheres Containing Carbon-Monoxide and Hydrogen	
By W. B. Hoyt and R. H. Caughey.....	21
Corrosion of Metals at Mandapam Camp, India	
By K. S. Rajagopalan, M. Sundaram and P. L. Annamalai.....	25
Case Histories and Ratings vs Corrosives of Polyester Fiber Glass Equipment	
By Robert E. Barnett and Thomas F. Anderson.....	29
DISCUSSIONS	
Observations on the Mechanisms and Kinetics of Aqueous Aluminum Corrosion. Part 1—Role of the Corrosion Product Film in Uniform Aqueous Corrosion of Aluminum. Part 2—Kinetics of Aqueous Aluminum Corrosion: P. M. Aziz and Hugh P. Godard, Page 36, Reply by R. L. Dillon, Page 36.	
Oil Refinery Applications of Thick-Film Synthetic Coatings: Charles M. Stanbury, Emile E. Habib, Austin K. Long, DuWayne Christofferson, Page 36; Reply by R. W. Maier, Pages 36 and 37.	
Impedance Characteristics of Isolated Aluminum Oxide Films: F. E. DeBoer, Page 37; Reply by D. F. MacLennan, Page 37.	
Behavior of AZ 63 Alloy and Magnesium—1 Percent Manganese Alloy Anodes in Sodium Chloride Electrolyte: J. L. Robinson, Page 37; Reply by J. H. Greenblatt, Page 37.	
Performance of Organic Coatings in Tropical Environments: Seymour J. Fiebach, Page 37; Reply by A. L. Alexander, Page 37.	
Corrosion Resistance of Titanium and Zirconium in Chemical Plant Exposures: E. G. Brink, Wayne H. Keller, Page 37; Milton Stern and Claude R. Bishop, Page 38; Reply by P. J. Gegner, Pages 37 and 38.	
Corrosion of Types 316 and 317 Stainless Steel by 75 Percent and 85 Percent Phosphoric Acid: C. M. Schillmoller, Page 38; Reply by A. R. Morgan, Page 38.	
Cathodic Protection of Lead Cable Sheath: R. B. Mears, L. C. Eddy, Vernon B. Pike, Frank E. Kulman, J. J. Pokorny, Pages 38 and 39; Replies by W. H. Bruckner, Pages 38, 39 and 40.	
Duct Anode Development and Experience in Protection of Underground Cables from Corrosion: David T. Jones, Page 40.	
Stress Corrosion Cracking of Oil Country Tubular Goods: H. Lee Craig, Jr., Joe Chittum, Page 40; Reply by R. L. McGlasson, Page 40.	

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# CONTENTS

## INDEX TO VOLUME 15 (Facing Page 40)

Table of Contents to Technical  
and Technical Topics Sections  
Alphabetical Subject Index

Alphabetical Author Index  
Subject Index, Corrosion Ab-  
stracts Section

Title Page, Volume 15  
Errata—Volume 15

## NACE NEWS

	Page		Page
Pittsburgh Section Plaque.....	69	Technical Meetings Are Well Attended at October Conference in Cleveland .....	72
Trouard to Represent NACE on ASCE Committee.....	69	Southwestern Ohio Section.....	72
Friend Appointed NACE Repre- sentative for ASA.....	69	Chicago Section .....	72
Rutter Heads Committee to Plan Short Course .....	69	Kansas City Section.....	72
Western Region News		Eastern Wisconsin Section.....	72
Portland Section Plans April 27-29 Short Course .....	69	Detroit Section .....	72
Los Angeles Section.....	69	Northeast Region News	
San Francisco Bay Area Section.....	69	Philadelphia Section .....	72
Portland Section .....	69	Wilmington Section .....	72
South Central Region News		Successful Conference Held at Denver.....	74
Tulsa Section Sponsors 11th Annual Short Course.....	71	Two Chairmen Named to Head Work on Plastic Coated Pipe.....	74
Central Oklahoma Section Plans 1960 Short Course.....	71	Photos of Denver Conference.....	74
Alamo Section .....	71	Several Denver Meetings Had "Standing Room Only".....	75
Tulsa Section .....	71	About 600 Attend Busy Sessions at Regional Meeting.....	75
East Texas Section.....	71	J. A. Caldwell Appointed to Board of Directors.....	75
Houston Section .....	71	Technical Tours Held.....	75
Shreveport Section .....	71	Annual Fellowship Hour.....	75
LaQue to Address Joint NACE- ASTM Meeting Feb. 9.....	71	Corrosion of Anodic Surfaces Is Controlled by Electrical Method.....	76
North Texas Section.....	71	Section Calendar .....	76
Corpus Christi Section.....	71	15 Symposia Co-Chairmen Listed for 1960 Dallas Conference.....	78
Canadian Region News		6 NACE Members Teach at California Short Course .....	78
Edmonton Section .....	71	Southeast Region News	
Conference Dates .....	71	Atlanta Section .....	78
North Central Region News		East Tennessee Section .....	78
Photos of Cleveland Conference.....	72	National and Regional Meetings and Short Courses.....	79
Index to Corrosion Abstracts.....	109		
Index to Advertisers.....	120		

## TECHNICAL TOPICS

Characteristic Properties of Polyurethane Protective Coatings By E. R. Wells.....	93
Corrosion Control Practices in the Wilmington Water Flood Operation By C. H. Jones, Jr.....	99
Cathodic Protection of Southern Pacific's High-Pressure Products Pipe Line—Whole System Installed in Nine Months By D. N. Miller.....	104
Discussions .....	106

## Technical Topics Scheduled for January

Precision Parts Are Cast from Epoxy Resin  
Systems, by Elliott N. Dorman and Wil-  
liam Ibsen

Engineering Approach to a Chemical Plant  
Coating Program: Part 1—Records That  
Help Keep Track of Costs and Prove  
Results; Part 2—Training Men to Make  
the Program Work, by Newell B. Cas-  
dorph

Rust Preventive Properties of Nonylphen-  
oxyacetic Acid in Some Petroleum Prod-  
ucts, by Robert M. Pines and John D.  
Spivack

Corrosion Considerations in Selection of  
Rocket Engine Materials, by R. A.  
Geiger, Fred T. Schuler and Robert E.  
Mowers

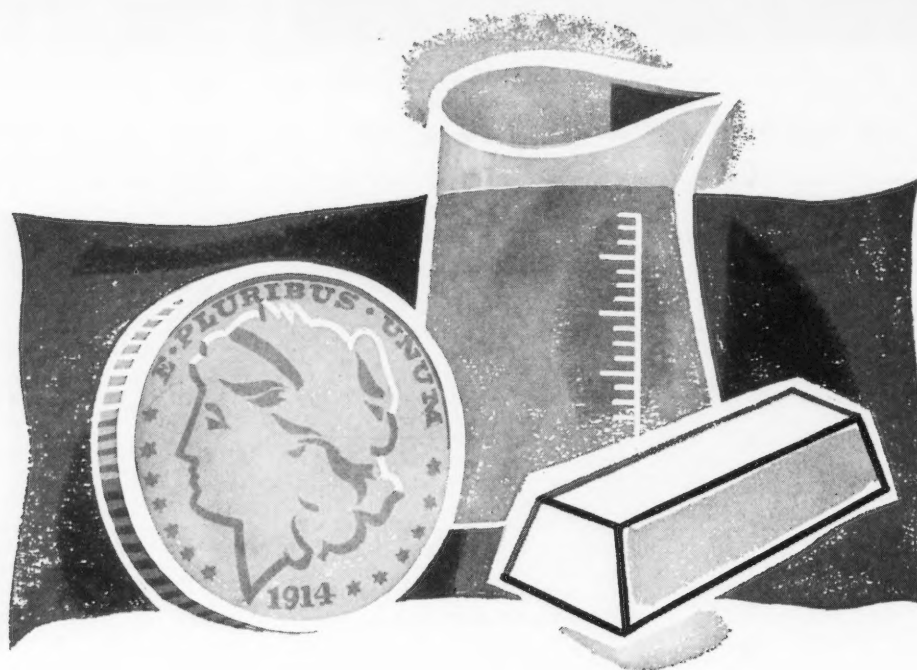
## GENERAL NEWS

	Page
Epoxy Resin Coatings Resist Intense Gamma Radiation .....	81
Belgian Corrosion Study.....	81
Book News .....	81
Porcelain Electrode Developed for Salt Study .....	82
Electric Cars May Use Nickel- Cadmium Batteries .....	82
Rapid Aluminum Welding.....	82
Plastic Engineers' Society to Meet January 12-15.....	83
Maintenance Conference .....	83
Metal Deformation .....	83
New Flux for Aluminum.....	83
Catalogs List Research.....	83
New Products .....	84
Men in the News.....	90

## REARRANGEMENT OF INSIDE PAGES

Beginning with the January 1960 issue, the inside con-  
tents of CORROSION will be  
rearranged from their pres-  
ent to the following se-  
quence, front to back: Con-  
tents Pages, Technical Topics,  
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ties, NACE News, General  
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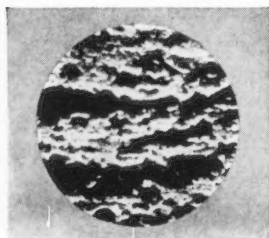
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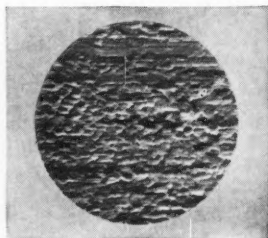
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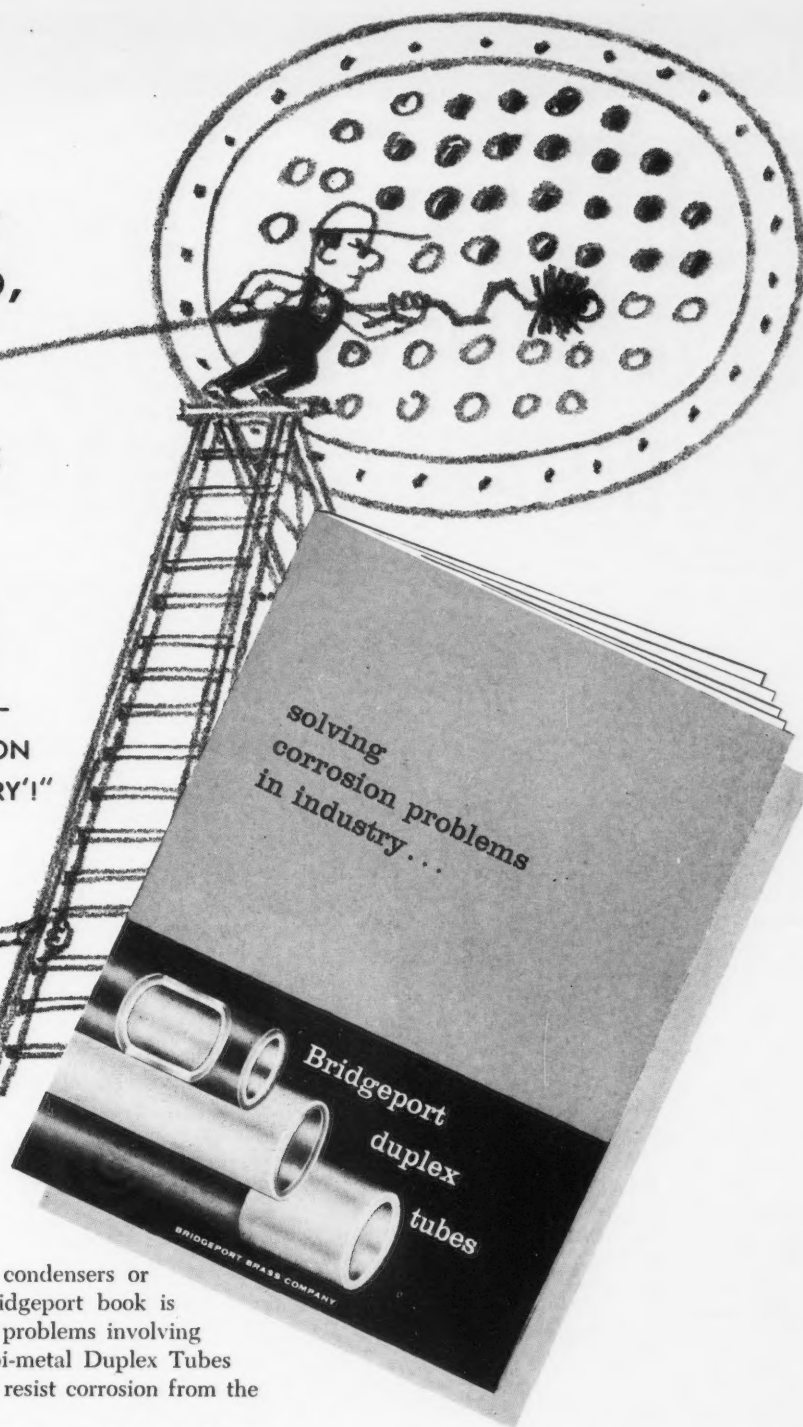
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Trade Size	1/2"	3/4"	1"	1 1/4"	1 1/2"	2"	2 1/2"	3"	3 1/2"	4"	5"	6"
KRALOY PVC	15.0	20.0	29.0	40.0	47.0	63.0	101.0	131.0	159.0	187.0	253.0	326.0
ALUMINUM	27.4	36.4	53.0	69.6	86.2	115.7	182.5	238.9	287.7	340.0	465.4	612.9
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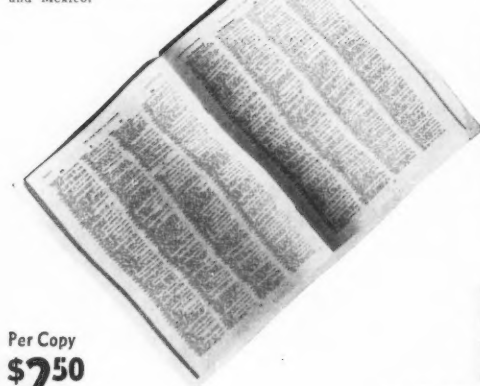
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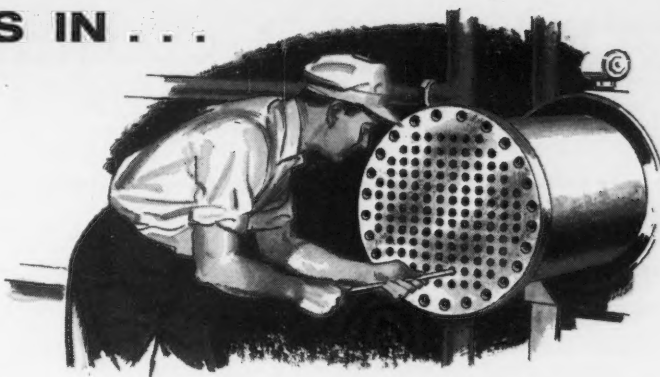
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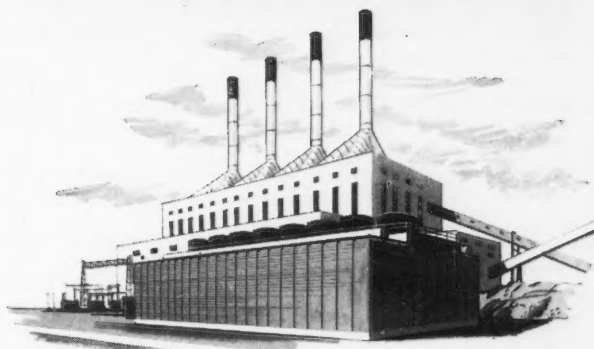
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## Corrosion in a Hydrocarbon Conversion System\*

By F. A. PRANGE

THIS IS ONE of a group of articles on high temperature corrosion describing elusive problems. Other articles concern themselves largely with metal loss. This paper considers some secondary effects which add to knowledge of the mechanism of damage.

A brief description of the butane dehydrogenation process<sup>1,2</sup> at Plains Plant of Phillips Petroleum Company will aid in understanding the conditions. Butane is dehydrogenated to butene over a chromia-alumina catalyst at a temperature of about 1100 F. Tubes of 2½ inch ID are used to contain the catalyst. At intervals the carbon which forms on the catalyst is burned off with regeneration gas of low oxygen content. During this phase the catalyst tube is kept hot enough to insure combustion, but the furnace gas serves to cool the tube. Low oxygen content is necessary to prevent the temperature during burnout from going too high and causing damage to the catalyst or carburization of the tube. Either the wrong alloy for tube material or carburization of the tube causes a red oxide dust to spread over the catalyst. This oxide dust is very catalytic and causes destructive cracking of the butane. Such severe cracking in turn results in a large amount of carbon and very rapid plugging. The whole undesirable process leading to oxide formation has been given the name "metal dusting."

The alloy for the plant tubes was selected on the basis of early pilot plant work. Some alloys gave very rapid plugging. The 27-chrome alloy and copper were inert. In the laboratory tests glass and silica were also inert.

After the 27-chrome tubes, welded into groups called harps, had been in use for some time, mechanical properties became critical. Exposure to operating conditions caused sigma phase to form and embrittle the tubes. At atmospheric temperature during the shutdowns for catalyst changes the 27-chrome was almost glass brittle. Because of considerable breakage, something better was desired.

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Laboratory studies made to find metals for miscellaneous parts led to use of 25-20 chrome-nickel for catalyst tubes and 18 chrome-11 nickel-2½ silicon steel for the headers.

The laboratory studies and plant tests of the special alloys demonstrated some of the factors in the high temperature corrosion in butane dehydrogenation equipment. The laboratory tests were made in the fashion described below:

The metals were abraded with a clean fine file and the chips were mixed with catalyst particles and placed in Pyrex tubing. Butane was passed through the mass for 50 minutes at a temperature of 1112 F. Gradually during the cycle, carbon formed on the catalyst and this was burned off with 50 minutes of regeneration with air. The performance of the metals was evaluated by pressure drop across the tube during the butane cycle, by the amount of carbon formed, by the amount of olefin formed, by the rate of plugging and by the appearance of the metal chips.

Metals that performed well produced only a nominal pressure drop during the dehydrogenation phase through a large number of cycles. A metal of intermediate performance might show only a normal pressure drop for as many as 15 cycles, but then practically plug in two more cycles. Very poor metals like carbon steel might plug in two cycles. Another characteristic of a very poor metal was that it degraded a great deal of the butane to products of lower grade than the desired butenes. The appearance of the metal also was important: Poor steels were completely covered with velvety buds of red oxide after the carbon was burned away; good metals showed few, if any, buds of oxide.

Composite ratings of some metals are shown in Table 1. In these tests high silicon cast iron plugged badly even before one regeneration cycle had occurred. Nickel had such a rapid buildup of carbon during the butane phase of the first cycle that it was impossible to pass butane through the mass for the full 50 minutes.

While the 27-chrome harps were in use and after the laboratory tests, full scale tube tests were made in the plant. The test materials are shown in Table 2.

### Abstract

Under some inexactly defined conditions, steels and alloys are attacked by atmospheres resulting from oxidation of hydrocarbon. In a fixed-bed catalytic system for dehydrogenation of butane the metal loss which contaminates the catalyst with a fine oxide dust causes undesirable side effects. The way in which the metal loss occurs is described and the effects of alloying agents on both laboratory tests and actual equipment are mentioned. Some examples of metal dusting give a clue to the mechanism of metal loss, but are not complete enough to define it fully.

4.4.6

### About the Author



F. A. PRANGE is employed by the Engineering Department of Phillips Petroleum Company. Since he joined the company in 1941 he has been working on the varied problems in corrosion and metallurgy connected with the production of and refining of oil and various processes. He was granted a BS in metallurgical engineering by Purdue University in 1940 and an MS in 1941.

Of these test metals only 302B, 310 and 316 tubes did not plug. The 316 tubes, though they did not plug, were always sluggish on burnout during the regeneration cycle. This indicated that the carbon formation was excessively high.

TABLE 1—Ratings of Metals in Dehydrogenation Tests

Good	Poor
31 Cr-9 Ni	20 Cr-3 Ni
27 Cr	18 Cr-11 Ni
24 Cr-15 Ni	17 Cr-13 Ni-2 Mo
20 Cr-10 Ni-3.6 Mo	12 Cr
18 Cr-12 Ni-2.5 Si	9 Cr-1.4 Mo
30 Cr-65 Co-4 W	Duriron (High silicon cast iron)
	Iron
	Nickel

TABLE 2—Analysis of Metals Used in Plant Tests

AISI Type Number	Nominal Analysis
302B.....	18 Cr-11 Ni-2½ Si
304.....	18 Cr-10 Ni
310.....	25 Cr-20 Ni
316.....	16 Cr-13 Ni-2 Mo
321.....	18 Cr-11 Ni-0.4 Ti
347.....	18 Cr-12 Ni-0.9 Nb

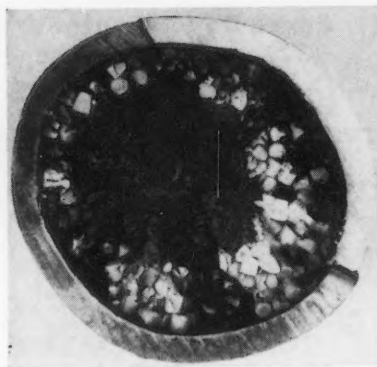


Figure 1—Catalyst tube containing rat-tail file. This shows how the iron-containing coke spreads outward in a radial fashion.



Figure 2—Carbon spreading inward from wall of a carburized tube.



Figure 3—Catalyst in Inconel tube shows how the nickel oxide pervades the entire catalyst mass.

After these tests were made, experimental harps of 302B and 310 analysis were installed. After a case fire overheated the tubes, the 302B tubes had loaded the catalyst with more dust than had the 310 tubes. The final decision was that the catalyst tubes were to be of 310 stainless and the headers of 302B stainless. The plant presently is using this equipment.

The discussion of metals in butane dehydrogenation is not complete without adding other information. Clues to the mechanism of damage are available in other incidents.

In one instance a carbon steel file was left in a tube as it was being filled with catalyst. After a short time on stream the tube plugged and was removed from service. When the carbon was partially burned off, the pattern shown in Figure 1 was apparent. The carbon "grew" outward in a radial fashion pushing the catalyst ahead of it. There was also some general contamination with oxide dust.

Figure 2 shows carbon formed in 27-chrome tubes after the tube became carburized due to fires in the catalyst case. The addition of a small amount of carbon very markedly damages the alloy. Carburization is a frequent cause of plugging. Apparently, chromium combined with carbon in the form of carbides is ineffective in preventing dusting.

To study the dusting process an Inconel tube (15% chromium, 7% iron, 78% nickel) was installed. This tube started to plug in a short time. Figure 3 shows how nickel oxide pervades the entire catalyst mass instead of being concentrated near the wall as in the carburized 27-chrome tube or near the contaminating source such as the file. The rate of migration of nickel is much higher than that of iron—not only in plant equipment but also in laboratory tests.

It was thought at first that the catalytic effect of steels had little relation to general metal loss. On this premise the case headers conducting the harp effluent gases away were made first of 5-chrome steel. From the standpoint of temperature alone—temperatures under 1100 F—the 5-chrome should have been adequate. Instead, general metal loss of a



Figure 4—Electron microscope picture of the iron oxide attached to a catalyst particle. Approx. 10,000 X.

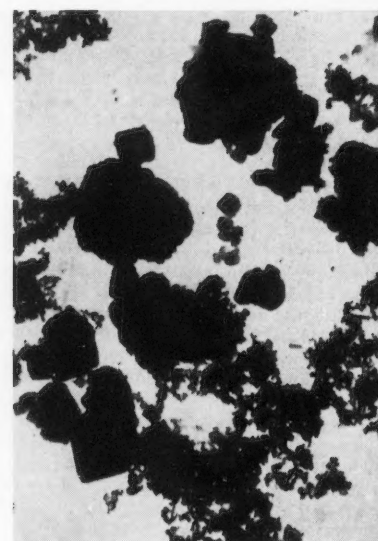


Figure 5—Electron microscope picture of nickel oxide attached to catalyst particles. 10,000 X.

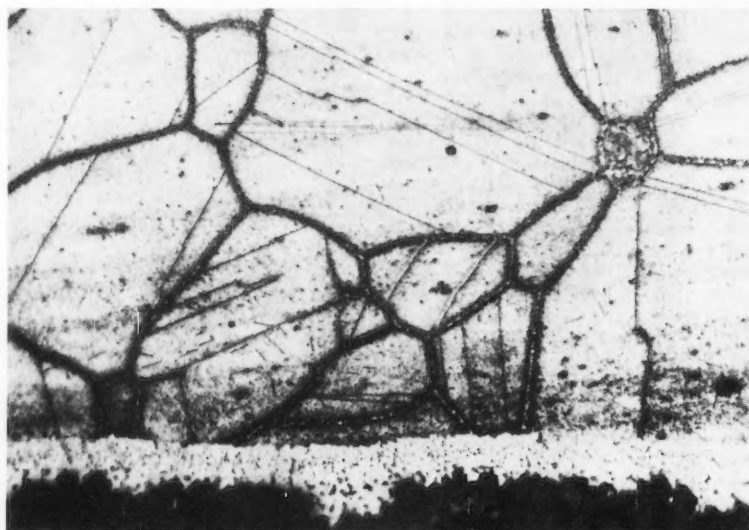


Figure 6—Elemental nickel layer on inside of a slightly carburized tube. Chromic acid etch. 250 X.

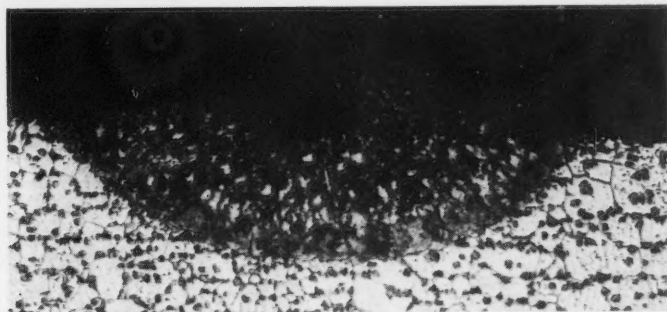


Figure 7—Very localized carburization in a 27-chrome catalyst tube. Aqua regia etch. 75 X.

peculiar fashion occurred. The metal disappeared in such a uniform way that the thread form on internally threaded parts was unchanged while the diameter increased a few tenths of an inch. No scale was formed; there was just a fine red oxide on the surface. Twelve-chrome steel was used for replacement, but this suffered the same type of damage, although the damage was somewhat slower. The general metal loss in the effluent lines finally was cured by using austenitic stainless equipment. This is but one of the experiences throughout Phillips operations that demonstrates that ordinary ideas of high temperature resistance do not apply to environments that are alternately oxidizing and reducing.

The resistance to the dusting action can be changed by small changes in analysis. In the chromium-iron series, 17 chrome was completely unacceptable while 27-chrome material was a commercially useful material. The austenitic stainless steels are even more sensitive to small changes in analysis. As might be expected from performance in 27 chrome-iron, 25-20 chrome-nickel steel performed well. From the performance of 17 chrome-iron it would not be expected that Type 304 stainless with about 18% chromium would be good. It was not. But Type 316 stainless with slightly lower chromium content and with the addition of 2% molybdenum was almost good enough. The addition of 2½% silicon to the 18-8 analysis gives even more astonishing results. This 2½% silicon variant is almost equivalent to 25-20 chrome-nickel. The extra 7% chromium of 25-20 can almost be replaced by 2½% silicon. Even on an atomic percentage basis the amount of silicon is less than the amount of chromium it replaces. Silicon by itself is not sufficient because the 14 silicon-iron alloy was extremely poor.

Analysis of the coke formed during operation gave some surprising results.

The coke around the iron file mentioned previously contained magnetite ( $\text{Fe}_3\text{O}_4$ ) and graphite as the only compounds with X-ray diffraction patterns. Metallic iron was not present nor was there any evidence of metallic carbides such as  $\text{Fe}_3\text{C}$  and  $\text{Fe}_2\text{C}$ . After carbon was burned off this coke, the only compound giving a pattern was  $\text{Fe}_2\text{O}_3$ . The electron microscope picture, Figure 4, shows that the resulting  $\text{Fe}_2\text{O}_3$  is in a tree-like form.

The nickel oxide from the Inconel catalyst tube is shown in Figure 5. Coke in the Inconel tube contained only NiO and graphite. No metal particles, at least of the size capable of giving definite pattern, were present. Thus, these X-ray diffraction studies on both iron and nickel alloys lend no credence to the theory occasionally mentioned that actual grains of metal are popped out and that metallic particles are the actual catalytic agent forming the undesired coke.

The curious nature of the corrosion process is illustrated by another example. After 10 years of service one of the 302B experimental catalyst tubes was removed because of bulging and coking. Scale on the outside of the tube indicated that it had been overheated. This overheating could have been the result of a fire in the furnace or it could have been simply a function of excessive coke formation. On the inside of the tube there was a thin black scale. Analyses by X-ray diffraction showed graphite, magnetite ( $\text{Fe}_3\text{O}_4$ ) and metallic nickel. Figure 6 shows the details of the inside surface. The metallic nickel looks almost like a porous plating, as though the nickel had been deposited on this area after removal from some other area. The grain boundary appearance indicates that some carburization of the base material had occurred. There was no evidence of any grains being pried out.

Just how localized carburization can be is illustrated in Figure 7. Either the carburization is just beginning or there

were very few exposures to damaging conditions.

None of the foregoing phenomena adequately define the corrosion mechanism. While a few aspects are discernible, the picture as a whole is hazy. At first glance it might seem that oxidation phenomena govern the entire problem. This is contradicted by copper which has good metal dusting properties but poor oxidation resistance. Even in the stainless steel series, experience refutes a premise that oxidation resistance constitutes the entire variable. Type 316 stainless, which is not recognized as being more oxidation resistant than Type 347, is much better as a catalyst tube material. Although molybdenum detracts from oxidation resistance in some instances, it is beneficial to the dusting problem. Likewise, Inconel, which has superior oxidation resistance, performs poorly in butane dehydrogenation service.

To the author it seems that the movement of metal is best explained by a concept of a very unstable vapor phase compound. Examination of this thesis requires intricate techniques because ordinary analytical procedures cannot be used to study the highly unstable materials. Perhaps high temperature spectroscopy would aid in study of the problem.

#### Acknowledgments

Preceding details include the work of the Phillips' research department in studying laboratory techniques and conducting plant studies at Phillips Plains Plant. The work of a great many people is gratefully acknowledged.

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#### DISCUSSION

##### Question by William B. Segraves, Decatur, Ga.

In your laboratory test work did you try to pinpoint whether the reaction part or the regeneration part of your process cycle caused your metal dusting problem? This is in contrast to operating alternately on reaction and regeneration.

##### Reply by F. A. Prange:

Apparently the metal loss in the butane dehydrogenation process occurs during the reduction cycle. As mentioned in the discussion of Duriron, plugging with a few alloys started before the first regeneration cycle had occurred. "Buds" were clearly discernible during the first hydrocarbon exposure.



# Attack on Metals by Synthesis Gas From Methane-Oxygen Combustion

By F. EBERLE and R. D. WYLIE

## Introduction

AN UNUSUAL case of metal wastage of uncooled gas deflection baffles, soot blower elements and other components of AISI Type 347 (18Cr-8Ni-Cb) and AISI Type 310 (25Cr-20Ni) in contact with hot "synthesis" gas occurred in the waste heat boiler of a synthesis gas reactor after only three weeks of initial operation. The gas was generated by burning methane with oxygen under controlled conditions and consisted predominantly of CO and H<sub>2</sub> with some water vapor and entrained, finely divided graphite carbon. Subsequent investigations revealed that this wastage took place within a temperature interval of about 1650 F and 900 F.

## Design And Construction Features of Operating Unit

The operating unit consisted of a cylindrical steel tower, about 70 ft high with an inside diameter of 11 ft. Its functional details are apparent from the simplified section diagram shown in Figure 1. The lower part of the tower,

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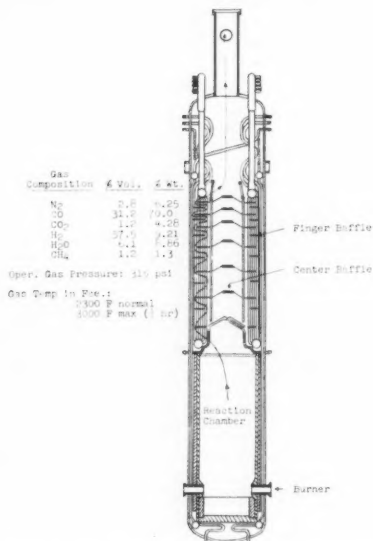


Figure 1—Simplified diagram of gas generator-waste heat boiler.

about 27 ft high, contained the alumina fire brick lined furnace (a pressurized reaction chamber) with circularly arranged water-cooled burners near the bottom end. In this furnace, natural gas (methane) was burned with oxygen, recovered from the air and concentrated 90 percent, under controlled conditions so as to obtain "synthesis gas" intended for hydrocarbon synthesis by a modified Fischer-Tropsch method. This reactor was designed for a gas pressure of 347 psi and an operating pressure of 315 psi. The gas temperature in the furnace normally was to be 2300 F with a maximum of 3000 F for not more than 1/2 hour.

Above the reaction chamber was a waste heat boiler designed for steam of 675 lb pressure. This waste heat boiler consisted of 11 vertical generating tube bundles and other boiler components, arranged in a circle around the inside wall of the tower, but leaving a central opening for the passage of the effluent gases from the reaction chamber. Cone-shaped baffles in this central opening, bolted to the surrounding boiler tubes with gusset plates, and alternating so-called finger baffles within the generating tube bundles to which they were attached deflected the upstreaming gases around the generating tubes, giving heat off to the latter and cooling down to 600-650 F at the outlet of the generator.

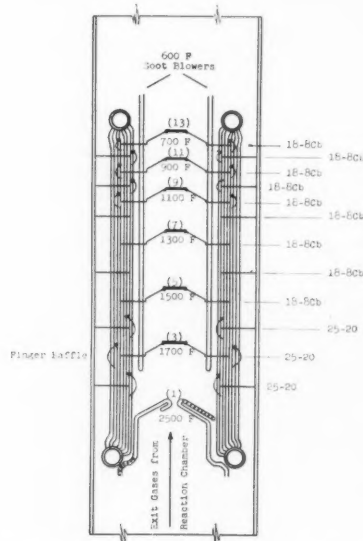


Figure 2—Approximate temperature distribution in waste heat boiler zone.

## Abstract

Severe metal wastage was experienced on AISI Type 347 (18Cr-8Ni-Nb) and AISI Type 310 (25Cr-20Ni) used in the construction of a gas generator in which methane was burned with oxygen to produce carbon monoxide and hydrogen for fuel synthesis of the Fischer-Tropsch type. The mode of attack varied with temperature. At the highest temperatures, above 1650 to 1800 F, it consisted of straight oxidation, progressing intergranularly. With decreasing temperatures, heavy carburization with occasional signs of interspersed oxidation manifested itself. As temperatures declined further, cycling carburization, oxidation and reduction were observed, accompanied by severe metal wastage.

Typically attacked metal surfaces consisted of a semi-scale containing tiny globules of metallic particles surrounded by carbon or graphite interspersed with oxide. Tests with specimens of numerous steels and alloys installed at various locations in the reactor showed that the most resistant materials were those which best resisted carburization, that is, nickel, Monel, Inconel, AISI Type 446 (27 chrome-iron), copper, and pack-calorized materials. 4.2.3



Wylie

Eberle

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R. D. WYLIE, assistant manager of quality control, The Babcock & Wilcox Company. He has a BS in metallurgical engineering, University of Michigan, 1944. After World War II duty with the navy and graduation from college he was employed at General Electric Company until 1948 when he joined his present employer as a metallurgist.

The internally water-cooled generating tubes never reached temperatures at which "wastage" occurred. Other significant elements involved in the wastage phenomenon were the sootblowing elements, tubing containing suitably arranged holes through which steam is blown over the boiler tubes to keep them free from deposits which would clog up the gas passages and interfere with heat transfer. There were 11 outer and 11 inner soot blowers, located before and behind the boiler tube bundles. The approximate temperature distribution in the waste heat boiler zone (explored with thermocouples) is indicated in the Section Diagram of Figure 2. These temperatures have been temporarily exceeded during some operating periods.

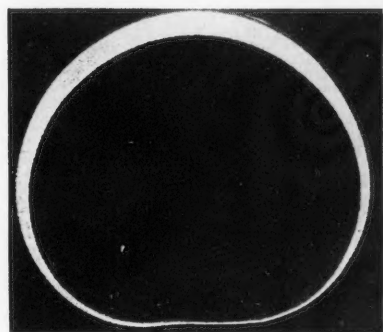
## Materials

The following materials were used for the construction of the major elements: The tower shell was made of 0.5Mo steel and the internally water-cooled





Approx. 1/3 X



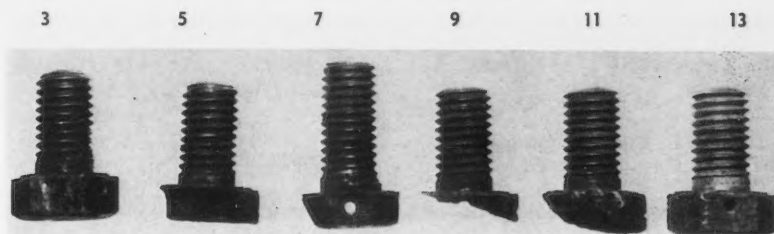
Approx. 2/3 X

Figure 3—Section of a "wasted" AISI Type 310 soot blower tube removed from location between Baffles 11 (about 900 F) and 13 (about 700 F).

boiler generating tubes of plain carbon steel. Their temperatures were so low that they did not become involved in the wastage phenomenon.

The lowest of the center baffles, which were all swept by the reaction gases, was constructed of water-cooled studded tubing covered with refractory reinforced with Inconel wire. The next hottest center baffle, No. 3, was made of AISI Type 310 alloy and all the others (Nos. 5, 7, 9, 11 and 13) of AISI Type 347 stainless steel.

The "finger baffles" which were located in the boiler tube bundles and attached to the latter consisted of the same materials as the nearest center baffles, that is, the three lowest and hottest finger baffles were made of AISI Type 310 and the remaining ones of AISI Type 347. All



Approx. 2/3 X

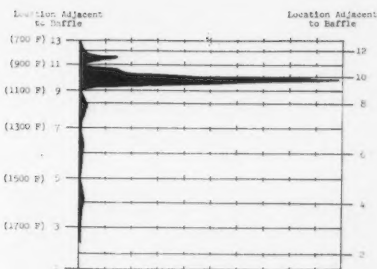
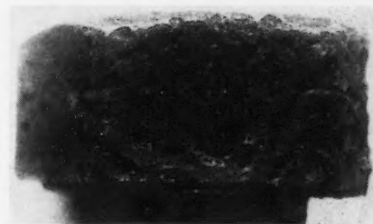


Figure 5—Percent diameter reduction of 25Cr-20Ni soot blower tube adjacent to center baffles.



Bolt from Baffle 3

Approx. 1.6 X

Figure 4—Example of corrosion of AISI Type 310 baffle bolts.

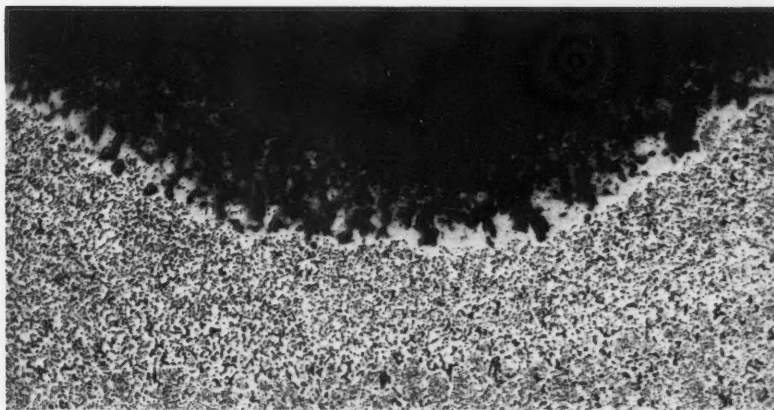


Figure 6—Oxidation-type pitting on surface of AISI Type 310 bolt of Baffle 3 (about 1700 F and possibly higher). Aqua regia etch, 100 X.

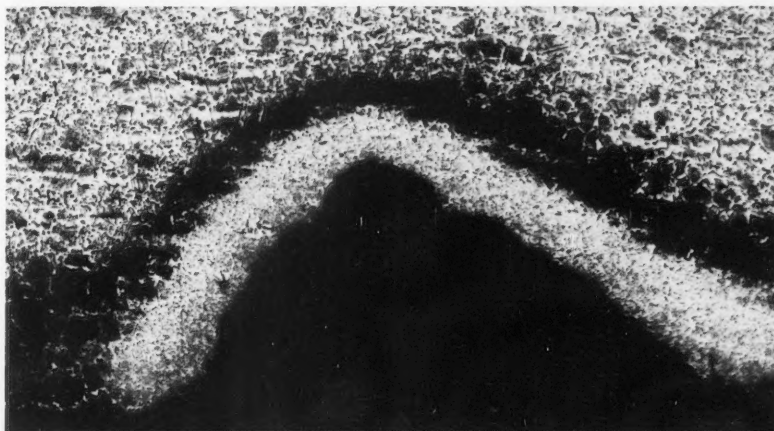


Figure 7—Example of pitting attack of the carburization-decarburization type observed on AISI Type 310 soot-blower tube between Baffles 5 and 7 (about 1500-1300 F). Aqua regia etch, 100 X.

baffle bolts whose heads were exposed to the hot gases, and the soot blower tubes were of AISI Type 310 alloy.

#### Results of Inspection After First Operating Period

The first operating period lasted only 21 days and was terminated because of

a failure of the burner cooling water circuit. During this time, the reaction temperature was out of control at least once. The plant had been operating only at about 15-25 percent of rated capacity with soot blowers active about every 30-45 min.

TABLE 1—Weight Changes of Material Samples Installed in the Generator During Second (14-Day) Operating Period

Material	PERCENT WEIGHT CHANGE AT BAFFLE					
	3	5	7	9	11	13
1 1/4 Cr-0.5 Mo.....	7	23.2	59.2	58.3	53.7	8.2
2 2/4 Cr-1 Mo.....	9.3	22.1	45.1	20.2	44	6
3 5 Cr-0.5 Mo.....	8.9	30.6	51.7	25.9	36.7	5.6
4 7 Cr-0.5 Mo.....	5.2	28.3	50.3	26.3	35.2	5.2
5 9 Cr-1 Mo.....	5.5	23	58	24	34.5	5.3
6 AISI Type 410.....	4.1	31.6	59.1	28	38.4	2.5
7 AISI Type 446.....	1.8	0.8	2.2	2	2.3	0.9
8 AISI Type 430.....	3	29.2	45	33.6	22.9	0.7
9 AISI Type 304.....	7.7	16.8	37.9	27.5	18.5	0.5
10 AISI Type 304L.....	5.7	16.2	41.2	23.3	17.6	0.5
11 AISI Type 316.....	4.7	19.1	28.8	15.4	12.4	0.1
12 AISI Type 316L.....	2.9	21.3	22	15.8	14.7	+0.5
13 AISI Type 347.....	2.9	6.2	23.4	16.4	27.5	+0.2
14 AISI Type 310.....	2.2	2.4	19.1	13.5	58.9	+0.1
15 Armco 17-14 CuMo.....	2.4	24.2	63.4	48	11.6	+0.8
AISI Type 304, Aluminized.....	+2.8	+2.3	8.5	...	1.3	6.9
AISI Type 310, Aluminized.....	2.2	2.2	7	...	1	2.7
Inconel, Aluminized.....	+1.2	+4.1	2	...	2.8	6.9
AISI Type 310, Ceramic Coated.....	3.7	8.6	58.6	...	2.9	2.2
AISI Type 304, Ceramic Coated.....	2.5	55	...	94.2	...	2.2
Carbon Steel, Ceramic Coated.....	2.6	...	82.1	...	...	18.2
Carbon Steel.....	...	...	39.5	...	...	...
CMo Steel.....	...	...	40.2	...	...	...
Copper.....	...	...	4.4-9.2	...	0.3	1.8-2.6
Aluminum Bronze.....	...	...	...	...	...	2.8

TABLE 2—Weight Changes of Material Samples Installed in the Generator During Third (41-Day) Operating Period

Material	PERCENT WEIGHT CHANGE AT BAFFLE					
	3	5	7	9	11	13
Carbon Steel.....	...	67.9	15.0	...	0.23	0.03
1 1/4 Cr-0.5 Mo.....	...	...	...	1.2	0.03	...
2 2/4 Cr-1 Mo.....	...	...	...	0.9	0.04	...
5 Cr-0.5 Mo.....	...	...	...	0.02	0.02	...
7 Cr-0.5 Mo.....	...	...	...	0.03	0.03	...
9 Cr-1 Mo.....	...	...	...	0.07	0.10	...
AISI Type 410.....	...	...	...	0.002	0.004	...
AISI Type 430.....	...	...	...	+0.002	+0.01	...
AISI Type 446.....	...	...	...	0.008	0.04	1.1
AISI Type 316.....	...	...	69.0	+0.003	+0.009	...
AISI Type 310.....	0.65	33.0	56.0	0.004	0.007	+0.4
18 Cr-35Ni.....	...	...	...	+0.02	...	...
Nickel.....	0.54	0.18	0.07	0.06	0.09	0.07
Monel.....	+0.21	1.0	17.6	0.09	0.035	0.04
Inconel.....	+0.04	0.9	+13.5	0.004	0.09	0.02
Copper.....	...	19.7	0.25	...	...	0.13
Carbon Steel, Pack Cal.....	...	70.0	40.0	0.23	0.06	0.04
1 1/4 Cr-0.5 Mo, Pack Cal.....	...	...	...	1.2	...	...
2 2/4 Cr-1 Mo, Pack Cal.....	...	...	...	0.10	...	...
5 Cr-0.5 Mo, Pack Cal.....	...	...	...	1.0	...	...
7 Cr-0.5 Mo, Pack Cal.....	...	...	...	0.07	...	...
9 Cr-1 Mo, Pack Cal.....	...	...	...	0.08	...	...
AISI Type 410, Pack Cal.....	...	...	...	+3.8	...	...
AISI Type 430, Pack Cal.....	...	...	...	7.7	...	...
AISI Type 446, Pack Cal.....	5.1	11.5	+5.7	0.04	0.06	0.06
AISI Type 304L, Pack Cal.....	...	...	...	0.95	...	...
AISI Type 347, Pack Cal.....	...	...	...	0	...	...
AISI Type 316L, Pack Cal.....	...	...	...	0.03	...	...
AISI Type 310, Pack Cal.....	...	...	...	2.0	...	...
17-14 CuMo, Pack Cal.....	...	...	...	0.03	...	...
Monel, Pack Cal.....	...	...	...	0.02	...	...
Inconel, Pack Cal.....	...	...	...	0	...	...
Copper, Pack Cal.....	...	...	...	0.13	...	...
Carbon Steel, Spray Cal.....	...	...	26.2	...	+0.03	0.47
1 1/4 Cr-0.5 Mo, Spray Cal.....	...	...	...	+0.015	...	...
2 2/4 Cr-1 Mo, Spray Cal.....	...	...	...	+0.002	...	...
5 Cr-0.5 Mo, Spray Cal.....	...	...	...	+0.014	...	...
9 Cr-0.5 Mo, Spray Cal.....	...	...	...	+0.10	...	...
9 Cr-1 Mo, Spray Cal.....	...	...	...	0.06	...	...
AISI Type 410, Spray Cal.....	...	...	...	0.07	...	...
AISI Type 430, Spray Cal.....	...	...	...	0.09	...	...
AISI Type 446, Spray Cal.....	0.55	2.6	0.29	0.08	0.06	0.07
AISI Type 304, Spray Cal.....	...	...	...	0.09	...	...
AISI Type 347, Spray Cal.....	...	...	...	0.016	...	...
AISI Type 316L, Spray Cal.....	...	...	...	0.025	...	...
AISI Type 310, Spray Cal.....	...	...	...	0.04	...	...

Visual inspection of the unit revealed that the lower section of the boiler tube banks was clogged with soot. The baffles, soot blower sections and related components in the 1700-1500 F temperature zone appeared to be relatively little damaged by corrosion, but all the uncooled structural components in the 1300-900 F gas zone had thinned to about one-half of their original thickness and some soot blower sections even to complete perforation. No damage was observed below about 800 F.

The type of corrosion encountered is illustrated in Figures 3 and 4.

In the high-temperature zone (1650-1700 F), the attack was of the pitting type. As temperatures decreased, it changed from a highly localized to a more or less general but still sporadic type of corrosion. The severest attack was observed in the general vicinity of 1100 F. This is indicated in Figure 5 which illustrates a wall-thickness survey made on one of the removed AISI Type 310 soot blower tubes.

#### Metallurgical Examination of Affected Parts

This severe metal attack which occurred in such a short time at relatively low temperatures in so-called heat and corrosion resistant alloys came as a complete surprise so efforts were made to determine its cause. For this purpose, affected soot blower tubing, bolts and gusset plate samples from each baffle were sent to the metallurgical laboratories for examination. This examination revealed the following:

In the highest temperature zone (1700 F and possibly higher), that is at the level of the lowest baffles, the attack consisted predominantly of straight oxidation which progressed in an intercrystalline manner with the formation of a semi-scale (Figure 6). Corrosion in this zone was not significant.

As temperatures decreased to 1500 F and lower, pitting corrosion set in, apparently initiated by localized carburization which was again followed by oxidation or decarburization (Figure 7).

With further decrease in temperature down toward 1400 F, carburization seemed to get the upper hand. In this predominantly carburizing zone, the attack was only slight (Figure 8). However, here also were sporadic occurrences of alternating carburization and decarburization.

At still lower temperatures, down to about 1100 F, cycling carburization and decarburization became the predominant phenomenon.

In some sections, carburization was found followed by decarburization and again by dense carburization (Figure 9).

A significant observation was the discovery, in a semi-scale, of tiny globules of metallic particles surrounded by carbon or graphite interspersed with oxide (Figure 10). Below this semi-scale was a thin layer of oxide and, underneath the latter, decarburized and carburized metal.

### Scale Analysis

Scale analysis failed to shed much light on the corrosion phenomenon. It revealed only the presence of iron oxide and graphite. In one case, X-ray diffraction lines of the compound  $\text{Fe}_3\text{C}$  were found. The technical literature reports that  $\text{Fe}_3\text{C}$  converts to  $\text{Fe}_3\text{C}_2$  at 1100 F.

### Corrosion-Resistance Evaluation of Materials With Samples Installed in the Generator During Second Operating Period

In order to explore the possibility of finding materials of greater resistance to the observed attack than the AISI Type 347 and AISI Type 310 stainless steels, test specimens of various alloys and non-ferrous metals were installed at each center baffle location of the unit during the subsequent operating period which consisted of two short runs of 4 and 10 days, respectively. These materials, listed in Table 1, were plain carbon steel, the conventional chromium-molybdenum high-temperature steels, the ferritic straight chromium and the austenitic iron-chrome-nickel stainless steels as well as other metals and alloys such as oxygen-free copper and aluminum bronze. Also included were ceramically coated specimens of carbon steel, AISI Types 304 and 310; pack-calorized AISI Types 304 and 310; and aluminized samples of AISI Type 304, AISI Type 310, and Inconel.

The samples had been measured and weighed before installation, but the resulting dimensional changes and weight losses proved to be of limited value for quantitative metal-loss evaluation because of the non-uniformity of the corrosive environment and the highly localized nature of the attack. Evaluation of their relative corrosion resistance therefore had to be based on over-all considerations of the extent of corrosion observed.

Some representative samples from each baffle location were metallographically examined to determine the nature of the attack. The latter was found to parallel that observed in the previously investigated generator components, that is, at Baffle 3 (highest temperature) the attack was caused by oxidation in the absence of carburization; at Baffle 5, carburization and oxide penetrations were in

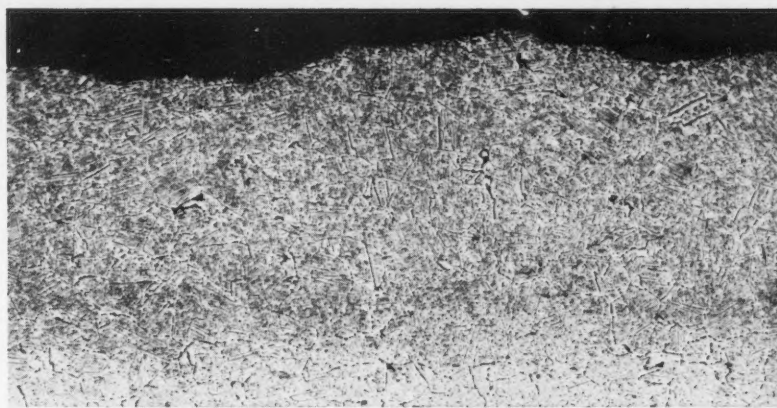


Figure 8—Mild surface attack on AISI Type 347 gusset plate of Baffle 5 (about 1400-1500 F). Only carburization in evidence. Aqua regia etch, 100 X.

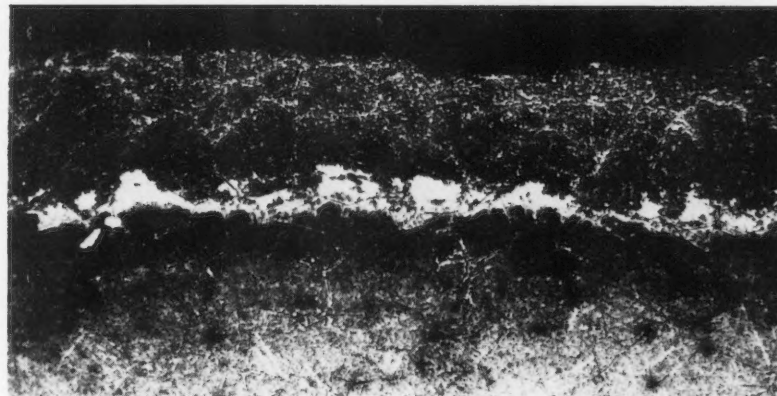


Figure 9—Metal attack at Baffle 9 (about 1100 F), showing a decarburized layer in the center of heavily carburized surface of AISI Type 347 stainless steel. Aqua regia etch, 250 X.



Figure 10—Semi-scale of graphitic carbon with imbedded iron particles, separated from base metal by a thin layer of oxide. Surface of AISI Type 347 gusset plate of Baffle 9 (about 1100 F). Unetched, 750 X.

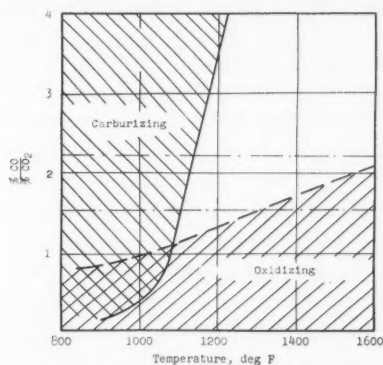


Figure 11—Effect of  $\text{CO}:\text{CO}_2$  ratio on carburizing-oxidizing atmosphere in contact with iron at temperatures between 800 and 1600 F.<sup>2</sup>

evidence; at Baffle 7, carburization combined with surface decarburization; at Baffle 9, heavy carburization and carbide concentration at the surface sometimes with and sometimes without surface decarburization, while in other cases a decarburized layer was present below the surface in the center of a carburized zone. At Baffle 11, corrosion was of the same general type as at Baffle 9, but its intensity was markedly decreased. At Baffle 13, corrosion was barely noticeable.

In summary, the attack was relatively light in the high-temperature zone (above about 1650 F) and ceased below about 900 F, but was severe and rapid at the intermediate temperatures.

The over-all evaluation of the materials revealed that those which suffered the least attack were all materials which resist carburization, that is, nickel, Monel, Inconel, 27Cr stainless, copper, and pack-calorized stainless steel.

For further confirmation of these findings, additional corrosion specimens were installed in the generator during the subsequent operating period which consisted of two 8-day and one 25-day runs, totaling about 1000 hours of exposure. The various materials used and the weight changes resulting from these tests are listed in Table 2. Nickel, Monel and Inconel again proved to be the most corrosion-resistant materials. The sever-



est corrosion observed in the last two alloys was some shallow intergranular attack.

### Discussion

The observations made during the examination of the affected metal parts and test specimens led to the conclusion that the following factors may have been involved in the wastage phenomenon:

#### 1. Oxidation at Cycling Temperatures.

Oxidation alone, observed only at the higher temperatures below the water-cooled baffle, appears to have been a minor cause. It manifested itself in the form of pits.

2. **Cycling Carburization and Oxidation.** This could have caused a "dusting" of metallic particles, possibly facilitated by thermal stresses due to sootblowing and by abrasion by particles entrained in the gas stream.

3. **Cycling Oxidation and Reduction.** It appears to be possible that surface oxide formed during sootblowing with steam was reduced to iron and graphite during the subsequent off-cycle. This possibility is supported by the metallo-

graphically found presence of metal particles in a graphitic-appearing deposit as well as by X-ray diffraction identification of graphitic carbon and traces of iron-graphite FeC on one of the affected soot blower elements.

4. Partial conversion of the outermost surface to solid carbide by continuous carburization and flaking off of the brittle layer.

The formation of iron and nickel carbonyl is not believed to have been a significant factor in the corrosion phenomenon. At the high temperatures at which wastage was observed, carbonyls are not apt to form. This is supported also by the fact that analysis of metal layers removed from affected surfaces of AISI Type 310 alloy has shown no changes in nickel content. Cycling or oscillating carburization and oxidation, or, oxidation and reduction therefore appears to be the most likely fundamental process involved. This possibility is indicated in the diagram of Figure 11 which shows the change from a carburizing to an oxidizing atmosphere as related to the CO:CO<sub>2</sub> ratio of such a gas

mixture in contact with iron at temperatures between 800 and 1600 F. An analysis of the problem from this point of view appeared to be hopeless due to the continuous variations of gas composition, temperature, and pressure existing during the operation of the generator.

### Reference

1. Symposium on Furnace Atmospheres for Metallurgical Purposes. The American Chemical Society Division of Gas and Fuel Chemistry. Detroit, 1940.

### DISCUSSION

**Question by Andrew Dravnieks, Standard Oil of Indiana, Whiting, Ind.:**

Were pack-calorized metals of any merit?

**Reply by F. Eberle, Babcock & Wilcox Co., Alliance, Ohio:**

Our yardstick for measuring the merit of a material or coating was whether it would resist the action of the gases sufficiently to give an economical life expectancy. By this token, none of the materials or coatings was rated satisfactory. The involved structural members were therefore redesigned for water cooling to keep metal temperature low enough to prevent metal attack.

## DISCUSSIONS ON TECHNICAL ARTICLES ARE SOLICITED

Discussions on technical articles published in *Corrosion* will be accepted for review without invitation. Discussions must be constructive, accompanied by full substantiation of fact in the form of tables, graphs or other representative data and be submitted in three typewritten copies. In cases where illustrations are submitted, at least one copy of figures should be of a quality suitable for reproduction.

Authors will be sent on request a copy of the NACE Outline for the Preparation and Presentation of Papers.

Discussions will be reviewed by the editor of *Corrosion* and will be sent to the author of the paper discussed for his replies, if any. Publication will be in the Technical Section with full credit to the authors together with replies. Discussions to papers presented at meetings of the association may be submitted in writing at the time of presentation or later by mail to the editorial offices of *Corrosion*, 1061 M & M Bldg., Houston 2, Texas.

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# High Temperature Metal Deterioration In Atmospheres Containing Carbon-Monoxide and Hydrogen\*

By W. B. HOYT and R. H. CAUGHEY

## Introduction

METAL DETERIORATION may occur in many forms which can be divided into two general categories. The first consists of irreparable impairment to one or more physical characteristics caused by changes to the metal's structure; the second category is metal loss from the exposed surfaces caused by corrosion or erosion, or a combination of both. Deterioration as described in this article belongs in the second category.

Metal loss usually results from chemical reaction between metal and its surrounding environment. Product of the reaction may be soluble in the environment, for example, attack by acidic solutions, or scales may be formed as when steel is exposed to air at elevated temperatures. In either case, rate of metal loss will be accelerated by velocity effects which tend to remove the reaction products and provide fresh, full strength reactants.

Metal loss also can occur as the direct result of attrition caused by impinging particles or rubbing parts which tear and abrade the metal surface. Although this type physical attack does not depend on corrosion, a combination of erosion and corrosion probably will be more destructive than either effect in the absence of the other.

The type deterioration described here does not appear to fit the generally accepted corrosion mechanism by chemical attack or erosion by particles. In this case the metal has been attacked in gas mixtures whose constituents, taken singly, are known to be non-corrosive at the given pressures and temperatures. These gases are primarily hydrogen, carbon-monoxide, steam and methane with small percentages of carbon-dioxide, nitrogen and heavier hydrocarbons.

This article describes this particular type of metal deterioration, which is taking place in a plant producing gasoline from coal by the Synthol process.

## Plant Description

The plant in which this metal deterioration is occurring was designed to convert coal to gasoline and various petrochemicals. The plant consists of several units wherein the different process steps are carried out. The unit of primary concern in this article is the reforming unit in which gas is prepared

for synthesis reaction to form gasoline and related hydrocarbons. Figure 1 is a generalized flow plan of the affected equipment with the gas compositions, average temperatures and pressures. Gas compositions are shown as percentage ranges because the unit has been operated under slightly varying conditions to accommodate varying feed gas compositions and to obtain varying end point requirements. It has not been found practicable to explore the effects of variations within these ranges on the rate of metal attack. So far as is known, attack may occur under all or only selected balances of gas composition within these ranges.

## General History of Deterioration

Metal loss in this system was first discovered after about 3000 service hours at the hot end of Type 310 stainless steel tubes in secondary preheaters. The attack was inside the tubes exposed to feed gas with tube metal temperatures approximately 1200 to 1300 F. Stainless steel (25 percent Cr-20 percent Ni) plate linings in the hot outlet header of these same preheaters were severely pitted. However, no evidence of attack was observed on the hot transfer lines of Type 304 stainless steel between the secondary preheaters and reforming reactors exposed to the same atmospheric and temperature conditions. Also, the hard facing trim of the block valve plugs in these transfer lines was severely washed or eroded. This hard facing was of a foreign composition containing cobalt.

This unit contains five parallel systems

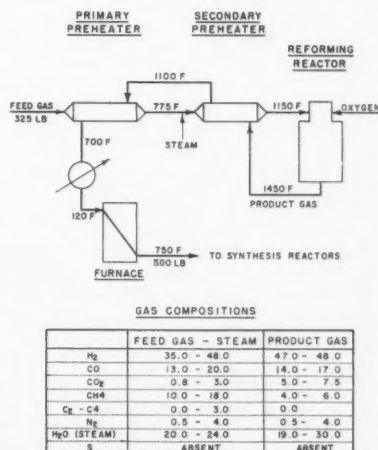


Figure 1—Generalized flow plan of equipment subject to metal deterioration.

## Abstract

Carbon steel and stainless steel equipment exposed to gas mixtures rich in hydrogen and carbon-monoxide at temperatures from 800 to 1200 F have been attacked with resulting loss of metal. Conditions under which this attack has been observed in a coal-to-oil synthesis plant and the nature of metal deterioration are described. Mechanism of this type attack is not fully understood although a possible gas-metal reaction is postulated. 3.2.2



Hoyt



Caughey

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W. B. HOYT has been materials engineer of M. W. Kellogg Company, New York, N. Y., for the past 15 years. He received his metallurgical training at Brooklyn Polytechnic Institute.

of preheaters and reactors to accommodate varying quantities of feed gas as the product of the preceding units in the train; consequently all the preheaters had been off and on operation several times. The original start-up and shut-down procedures included the use of air during heating and as part of the purge cycle; consequently, it was conjectured that attack might be caused by alternate carburization and oxidation. The operating procedures were changed to use nitrogen instead of air while the equipment is at temperatures over about 500 F.

After about a year of additional operation, leakage of the stainless steel tubes in the primary preheaters led to the discovery that these were being internally attacked at the hot end, similar to the attack in the secondary preheater tubes. At the primary preheaters, feed gas composition is the same except that steam has not been introduced; the tube metal temperature is approximately 900 to 1000 F.

For some time it was believed that no attack was being caused by the product gas from the reforming reactors. However, about the time that attack was discovered on the primary preheater tubes, a few carburized spots were observed on the stainless steel insulation shields in the secondary preheaters' shell side. Within the last year, the beginning of attack has been found on the outside surface of the tubes' hot end in the primary preheaters.

In addition to stainless steel deterioration under high temperature gaseous attack, severe metal loss also has occurred on carbon steel tubes in the synthesis gas furnace. Here the gas composition is the

\* Submitted for publication January 29, 1959. A paper titled "Metal Deterioration in Atmospheres Containing Carbon-Monoxide at Elevated Temperatures" presented at the 15th Annual Conference, National Association of Corrosion Engineers, Chicago, Ill., March 16-20, 1959. One of three papers on metal dusting sponsored by the ASTM-ASME Joint Committee on Effect of Temperature on Properties of Metals.

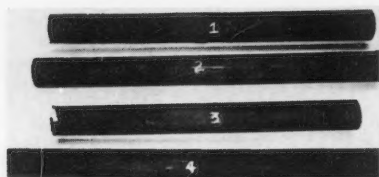


Figure 2—Tube failures in 1 1/4-inch O.D. by 12 gauge Type 310 stainless steel used in secondary preheater exchanger exposed to product gas. Metal temperature was from 1200 to 1300 F.

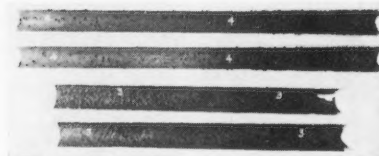


Figure 3—Pitting on inside surface of Type 310 stainless steel tubing in a secondary preheater exchanger, exposed to feed gas. Temperature range was 1200 to 1300 F.

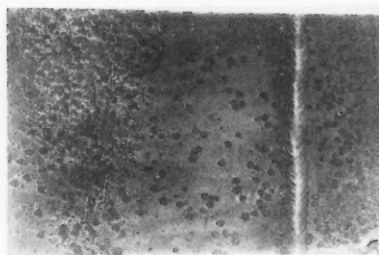


Figure 4—Pitting of Type 310 stainless steel plate lining in a secondary preheater exchanger's hot outlet header, exposed to feed gas.



Figure 5—Penetration failure of a Type 310 stainless steel tubing exposed to feed gas in a primary preheater exchanger. Tubing was 1 1/8-inch O.D. by 0.123-inch wall thickness. Metal temperature was 900 to 100 F.

same as the reformer product gas except that most of the water content has been condensed out.

#### Metallurgical Examination

Many material specimens removed from the affected equipment have been subjected to metallurgical examination to determine the mechanism of the attack with particular reference to the possible relationship of chemical composition, microstructure and mechanical properties of the materials involved.

#### Description of Samples Used

Representative tube failures which were removed from the secondary preheater unit are shown in Figures 2 and 3. The tubing is 1 1/4 inch outside diameter by 12 gauge minimum wall thickness of Type 310 stainless steel. Internally, they were exposed to the feed gas composition (Figure 1) and externally to the product or effluent gases. Metal temperature in the attack region was estimated to be from 1200 to 1300 F. Severe

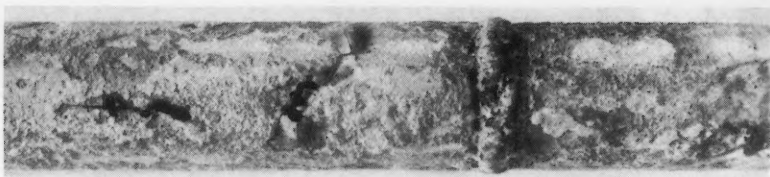


Figure 6—Failure of Type 310 stainless steel tubing in a primary preheater exchanger exposed to feed gas with metal temperatures from 900 to 1000 F. Tubing section at lower right was safe ended with Type 302B stainless steel.

pitting of the inside surface and general metal loss as evidenced by development of holes through the wall occurred at the downstream, or hot end, of many tubes after about 3000 service hours (4 1/4 months). No evidence of attack by the effluent gases was observed on the external tube surfaces other than formation of light oxide scale which discolored or blackened the surfaces.

Figure 4 shows the stainless steel plate lining removed from the hot outlet header of the same preheater which contained the tubing described. This lining was exposed to the same atmosphere but at a lower metal temperature than was the tubing. Although the surface was severely pitted, the degree of general metal loss was not as severe. The weld metal in the plate joint was not attacked. Also, the attack generally was sporadic with heavy metal loss at some locations and little loss at others.

Figure 5 shows a tube failure in the primary preheater exchanger. These samples represented 1 1/8-inch O.D. by 0.123-inch wall thickness Type 310 stainless steel tubes. The penetration failure of the tube wall shown in the top sample of Figure 5 occurred after about 1 1/2 years' service. They were exposed to the same feed gas composition as the secondary preheater tubes except that steam had not been introduced. Metal temperature of the tubes in the attack area ranged from 900 to 1000 F, or about 300 F cooler than in the tubes which failed in the secondary preheater unit. The attack was localized at the downstream or hot end of this unit.

Figure 6 is a tube from the primary preheaters, similar to tubing in Figure 5, which was safe-ended with a short section of new tubing of stainless steel, (High Silicon, Type 302B) after the original Type 310 material failed. This safe-ended tube was in service only about 1700 hours or 2 1/2 months when removal of the entire tube was necessary because of the serious attack immediately upstream of the safe end on the old section of Type 310 stainless steel. The latter sec-

tion, previous to safe-ending, had no apparent attack after about 10,240 service hours or 14 months. The excessive metal loss as evidenced by the marked wall thickness reduction and pitting of the Type 310 composition were in contrast with the behavior of the Type 302B safe-end material.

Probably more significant, however, is the fact that Type 310 tubing was free of any apparent attack for 14 months, but after only 2 1/2 months more, the damage shown in Figure 6 was experienced. This, it is believed, suggests that either an incubation period of uncertain duration may be necessary before rapid and damaging corrosion of the type shown will occur, or because of operational changes the prevailing and higher metal temperature of the hot end was extended upstream relative to safe-end location. The Type 302B composition safe-end in this case showed only mild attack in the form of sporadic carburization and pitting after the short exposure. Accordingly, it is not possible to conclude at this stage that the Type 302B composition offers a satisfactory substitute to minimize the effects experienced.

Little or no damage was experienced on external tube surfaces exposed to the product gases (Figure 1). In the past year, however, pitting attack has been found on the outside surfaces at the downstream or hot-end of the tubes in the primary preheater. Figure 7 shows this condition.

Although attack of the exchanger tubes and linings exposed to the feed gas in the secondary preheater had occurred, no attack of the Type 304 stainless steel transfer lines from this unit has been observed. The hard facing trim on the block valve plugs of these lines however, which were found to be badly attacked, was a stellite-like composition of foreign origin and contained cobalt. Figure 8 shows a cross section through this part. Notable is the almost complete loss of the hard face material (top of photograph).





Figure 7—Failure of Type 310 stainless steel tubing exposed to product gas in a primary preheater exchanger with metal temperatures from 900 to 1000 F.

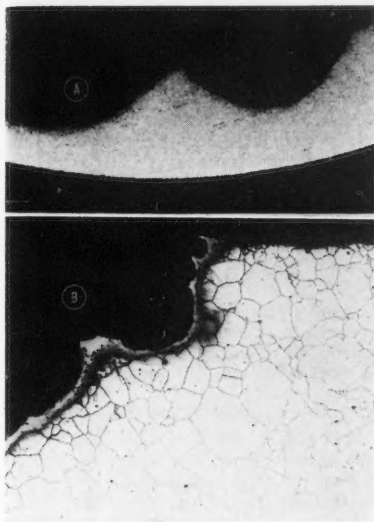


Figure 8—Cross section through block valve seat ring showing deterioration of hard facing, cobalt bearing trim used in a secondary preheater exchanger's hot transfer piping, exposed to feed gas conditions.

#### Results of Examination

Microscopic examinations of prepared specimens of each sample, supplemented by chemical analysis, X-ray diffraction, and ignition spectrographic procedures were used in checking the samples. In certain cases, supplementary mechanical tests were completed to further substantiate the observed effects.

Microscopic examination showed that in every case the severe surface pitting and heavy metal loss was associated with a surface phenomenon determined to be primarily carburization. Figures 9, 10, 11 and 12 are representative examples of surface conditions observed. Surface carburization was sporadic rather than uniform and more pronounced in the boundary surfaces of the pits than in the intermediate or surrounding plateau surfaces. Figures 10 and 11 are examples of this condition. Figure 11 is believed to show the pit formation in its initial stage in a highly localized surface spot. This represents an area where pitting of the surrounding surfaces was not visibly apparent. Carbon diffusion from the heavily carburized outer surface into the metal matrix takes place along a predominantly intergranular path. Figure 9 is a typical example of this.

General microstructure of the material observed in specimens representing locations far removed from the surface showed mostly evidence of intergranular carbide precipitation only. In the tube

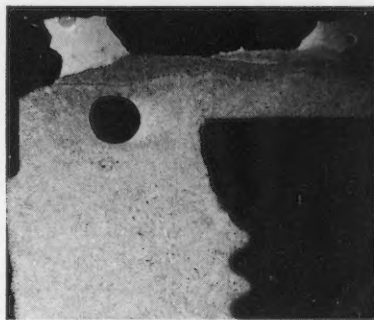


Figure 9—Photomicrograph of Type 310 stainless steel tubing's inside surface. Tubing was exposed to feed gas (1200 to 1300 F.) in a secondary preheater exchanger. Magnification 225X, Aqua Regia etch.

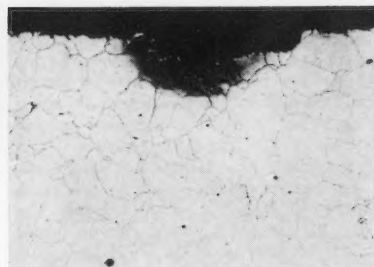


Figure 10—Photomicrographs of Type 310 stainless steel tubing exposed to feed gas (1200 to 1300 F) in a secondary preheater exchanger. Photo A is cross section, Magnification 5X, macro etched. Photo B is inside surface of tubing, microstructure, Magnification 45X, Aqua Regia etch.

samples from the secondary preheaters, this evidence was accompanied by sigma phase development. Figure 13 shows evidence of both structures. Presence of these phases was not unexpected for stainless steels exposed to these time and temperature conditions.

Chemical analysis on selected specimens confirmed that this effect was carburization. Sample drillings were taken from the I.D. surface of preheater tubing shown by photomicrographs in Figure 9. A similar analysis was completed on a new, unused spare tube. Results with particular reference to the carbon and nitrogen content are given in Table 1.

The high carbon content of the I.D. surface of the affected tubing is considered confirmation of the carburizing effect.

Supplementary X-ray diffraction and ignition spectrographic analyses on suitable specimens of these same materials, including carefully removed scrapings from the I.D. surfaces of affected tubing, failed to disclose the presence of unexpected or unusual residual elements in the base material composition which might be assessed as a contributing factor. No unusual corrosion compounds were found which might have been a clue to the attack mechanism. X-ray diffraction analysis showed only the presence of iron oxides on the surfaces. No chloride or sulphate was found.

Free bend tests and hardness explorations also were made on selected sam-

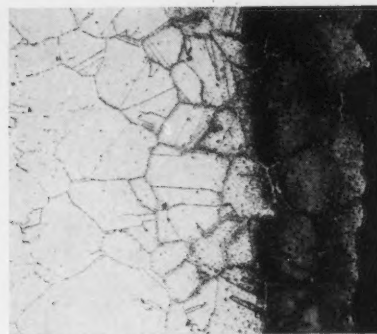


Figure 11—Photomicrograph of Type 310 stainless steel plate lining surface microstructure. Lining was used as hot outlet header in a secondary preheater, exposed to feed gas at 1200 to 1300 F. Magnification 225X, Aqua Regia etch.

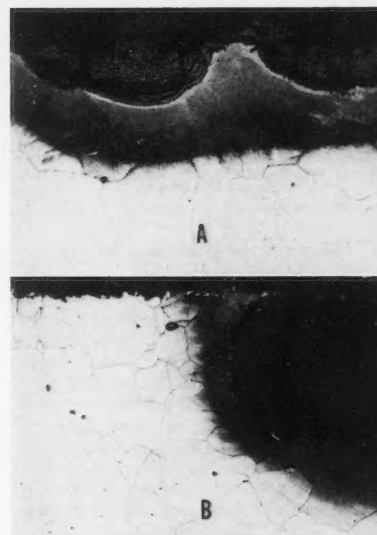


Figure 12—Type 310 stainless steel exchanger tubing. Microstructure of inside surfaces. Aqua Regia etched showing (A) primary preheater and (B) secondary preheater.

TABLE 1—Carbon and Nitrogen Content of New Tubing and Tubing Affected by Carburization Attack

Element	New Tubing	I.D. Surface Affected Tubing
C.....	0.06%	0.83%
N.....	0.072%	0.079%

ples of the affected material, and the results were compared with similar tests made on unaffected material. Affected areas were brittle and hard. With the I.D. surface in tension, bend tests failed with application of the load; with the O.D. surface of unaffected tubing in tension, 180-degree bending was possible without failure. Hardness of the inside surfaces ranged from a Brinell of 382 to 393, converted from Vickers micro hardness results. The unaffected tubing showed an equivalent Brinell of 205, considered normal for the manufactured tube product.

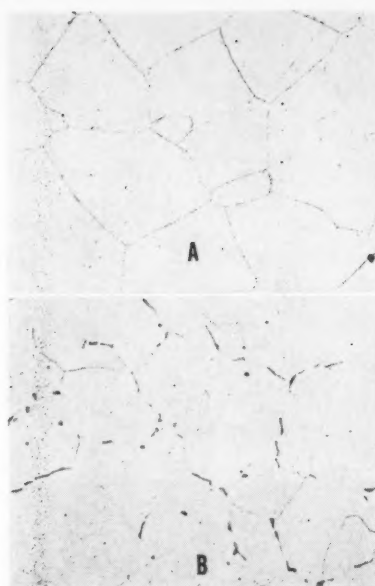


Figure 13—Microstructures of exchanger tubing made of Type 310 stainless steel in (A) primary preheater and (B) secondary preheater. Magnification 225X, Aqua Regia etched.

#### Discussion of Possible Theories

The metal loss described apparently does not fit the generally accepted ideas of corrosion by chemical attack or erosion by particles. Unfortunately, it has not been considered practicable to study this deterioration *in situ* by varying operating conditions individually or by comparing the resistivity of many different materials under identical conditions.

Successful operation of the plant forbids any appreciable changes in the operating conditions, and the integrated nature of the units does not permit continuous operation under steady conditions of gas composition. Furthermore, the expense involved in shutdowns to change tube materials or to install and remove samples has limited experimentation with new materials. Some work has been done with the exposure of samples of various materials in the hot outlet header of the primary preheaters and a few tubes have been safe ended with high silicon bearing Type 302B, aluminumized Type 304 and Incoloy 804. As yet there has been insufficient service time on these to permit definite conclusions.

Several theories have been advanced to explain this corrosion. It has been suggested that this is a form of acid attack caused by the entrainment of acidic constituents in the feed gas, which

is partially composed of re-cycled gas from the product recovery units. Before introduction to the reformer unit, feed gas is passed through a large water wash tower which reduces contaminants to a few parts per million. Some water mist possibly might be entrained in the gas which would evaporate on passage through the tubes of the primary preheater and deposit acid droplets on the hot surfaces. This theory is difficult to support because of the surface revealed by microexamination and because no corrosion products were detected on the tube surface.

Another theory is that the attack is the result of cyclic conditions in which the metal surface is carburized and then oxidized,<sup>1</sup> the thought being that carburization will effectively tie-up the chromium content, thereby destroying the normal oxidation resistance of the stainless steel. Although this sequence of conditions may have contributed to initial tube failure in the secondary preheaters, it does not explain subsequent attack after air was eliminated from the operating cycle. Also, if direct carburization of the metals by the gas atmosphere is a factor, it might be expected that the entire tube surface would be uniformly carburized instead of at local spots associated with pits.

A third theory which is considered worthy of careful consideration is as follows:

Under certain temperature and pressure conditions, some metals and metallic oxides catalytically promote the reaction of  $2CO \rightarrow CO_2 + C$ .<sup>2,3</sup> Three of the most active metals are Fe, Ni and Co; Cr and Mo are relatively inactive. The carbon resulting from this reaction is chemically active and, because it is formed at the surface of the metal, the carbon can readily combine to form the metallic carbide, thereby carburizing the metal structure. Carbon resulting from this reaction forms as threadlike filaments which contain within them nuclei of the metal carbide.<sup>4,5</sup>

Therefore, it seems reasonable to theorize that within certain ranges of gas composition, temperature and pressure the metallic container may catalytically participate in the decomposition of carbon monoxide, and thereby small metallic particles will be lifted from the surface by the forming threads of carbon which are fragile and easily carried away in the gas stream. Under borderline conditions, this catalytic activity may start at local points on the surface, thus resulting in pits as the catalytic activity spreads radially from the original point.

Only where this active reaction occurs is there carbon available to carburize the metal.

This theory seems to be supported by appearance of the tube's inside surface which reveals that the attacked area varies from pits in the cooler portion of the tubes to severe attack in the hotter portion where the individual pits merge. That each gas composition has its own optimum temperature range for attack is indicated by location of attack at different metal temperatures in the primary and secondary preheaters in which gas compositions vary because of the addition of steam between the two.

The catalytic aspects of this theory seem to be supported by the relative resistance of the different stainless materials in the secondary preheaters and transfer lines. The most severely attacked material was the cobalt bearing hard facing valve trim, yet Type 304 stainless valve bodies, transfer line pipe and replacement valve trim were not attacked. In comparison, the Type 310 plate lining in the hot outlet of the secondary preheaters was severely pitted. This lesser resistance may be ascribed to the greater nickel content which is not balanced by the slightly greater chromium content.

#### Summation

This article describes an unusual type deterioration which has been experienced on stainless steel equipment exposed to atmospheres containing carbon-monoxide and hydrogen at temperatures from 800 to 1300 F. This deterioration has taken the form of pitting and general metal loss without the formation of adherent scales but accompanied by carburization of the attacked metal surface. A tentative theory to explain this form of deterioration has been offered for consideration.

#### Acknowledgment

The authors wish to acknowledge with appreciation the cooperation of the company whose unhappy experience has made this article possible.

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# Corrosion of Metals at Mandapam Camp, India\*

By K. S. RAJAGOPALAN, M. SUNDARAM and P. L. ANNAMALAI\*

## Introduction

**F**IELD exposure has become a well-established method to study the performance of protective treatments and atmospheric corrosion problems. The Corrosion Committee of the British Iron and Steel Association has nearly 20 test stations located in different parts of the world. Corrosion is of interest to 12 Committees of the American Society for Testing Materials and field testing activities of this organization go back to more than 40 years. It is of considerable interest to India to know that a comparison of the corrosivity data collected by the organizations mentioned above has shown that the rate of corrosion of steel is highest in marine atmospheric testing stations like Kure Beach,<sup>1</sup> North Carolina, U.S.A.; Lighthouse Beach,<sup>2</sup> Lagos, Nigeria; and Christobal,<sup>3</sup> Panama Canal Zone. The latter two sites are located in the tropics.

India has a 4000-mile coast line and the climate prevailing in three-fourths of the land may be classified as tropical. It is in this context that the Central Electrochemical Research Institute decided to set up a corrosion testing farm at Mandapam Camp on the Southeast Coast to enable rapid assessment of various protective schemes. The location of Mandapam Camp and the Central Marine Fisheries Research Station in whose 80-acre campus the test farm of the Central Electrochemical Research Institute is situated are shown in Figure 1. It may be seen readily that tropical marine conditions are likely to be experienced in the severest form at this location. The monthly rates of corrosion of mild steel, zinc and copper at two sites located at 150 feet and 1350 feet from sea during the period November 1957 to December 1958 are reported in this paper.

## Experimental

### Description of Experimental Sites

**1350 Feet Site:** This is situated on the top of a hillock overlooking the sea on both sides. The site is 1350 feet from the Gulf of Mannar and one mile from Palk Strait. The wind direction is predominantly southwest and southeast for six months in the year (April to September) and northeast and northwest for six months (October to March).

**150 Feet Site:** The site faces the Gulf of Mannar and the stands are located on level ground 150 feet from the water.

### Methods of Exposure of Specimens

Open exposure was carried out on Monel and aluminum stands similar to those at the Kure Beach station of The International Nickel Co.<sup>4</sup> The stands were

## Abstract

Monthly rates of corrosion of mild steel, zinc and copper at two sites located 150 feet and 1350 feet from the sea are reported. Coupons were exposed in under both open and sheltered conditions on racks oriented at 45 degrees facing south.

Climatic conditions at the Mandapam Campsite are discussed in detail and means of keeping the records reported. Rates of corrosion of the test samples are discussed in relation to the observed climatic conditions. Differences between the open and sheltered tests are compared.

Among the conclusions: There is no direct relation between the corrosion rate, distance from the sea and atmospheric salinity, although salinity is an important factor in the rate. Highest rates were observed in months with high mean temperature and accompanying high average humidity and salinity. 2.22

held at 45 degrees south as in the case of exposure of painted metal. The bottom end of the specimen frame was 2 feet nine inches from the ground. The specimens were supported by porcelain cleats which prevented contact with the metal frame.

Stevenson screen was used for the sheltered exposure. The Stevenson screen is a wooden box with a double roof, double louvered sides and slatted bottom. It is a standard piece of meteorological equipment<sup>5</sup> in this country and in the United Kingdom and has been widely used by the Corrosion Committee of Britain in its studies.<sup>6</sup> It allows free circulation of air inside the box but entry of rain water is completely prevented. It is placed four feet from the ground on wooden legs. Both the small screen with internal dimensions 22½ inches, x 12½ inches x 16½ inches and the larger screen (53 x 12½ x 16½) were used in the present studies.

### Preparation and Cleaning of Specimens

Specimens measured 6 x 4 x 1/16 inch. They were abraded initially with O emery till a uniform finish was obtained. After abrasion, the specimens were degreased in methanol, hot benzene and acetone. Every exposure was carried out in duplicate and the mean of the two values which did not vary between themselves by more than 10 percent, was considered. The corrosion product of mild steel was removed by immersion in Clarke's solution for a period varying from 1 to 5 minutes depending upon the amount of rust formed. Care was taken to see that excess of stannous chloride was present and the solution did not turn yellow during derusting. The corrosion product on zinc<sup>8</sup> was removed by dipping for 1 to 2 minutes in sulfate-free chromic acid at 80 C and that on copper<sup>9</sup> by immersion in cold 5 percent sulfuric acid for 5 to 6 minutes. The weight losses obtained were corrected for blank loss. The chromic acid bath was discarded when it showed high blank losses following accumulation of chloride in the bath. Steel specimens were cut from



Figure 1—Location of Mandapam Camp.

mild steel sheets supplied by Tisco (C—0.1 to 0.2, Mn—0.4 to 0.5, phosphorus—0.3—0.8, and sulfur 0.02 to 0.03) zinc from commercially pure (99.8) zinc and copper from sheets of commercial purity.

### Determination of Atmospheric Salinity

The wet candle method described by Ambler<sup>2</sup> in which destarched surgical bandage is wrapped around a glass tube having an outside area of 1 sq.dm. and the two ends dipped in distilled water contained in a litre flask was employed.

## Results and Discussion

### Climatic Conditions at Mandapam Camp

Monthly averages of maximum and minimum temperatures, relative humidity, wind velocity and rainfall are shown in Figure 2. The meteorological station which supplied this data is located on a hillock on the other side of the 2 mile long Pambam Bridge shown in Figure 1. Owing to the nearness of the sea to both the places, it is not expected that there will be significant differences in regard to the climatic conditions at the two places. Common climatic conditions at the meteorological station and at the test sites has, therefore, been assumed and the results interpreted on this basis.

It is seen from Figure 2 that the average maximum temperature increases from 80 F in December, 1957, to 90 F in April, 1958 and falls during the latter part of the year. The difference between the maximum and minimum remains fairly steady around 9 F (5 C). The average relative humidity remains above 75% which is where sodium chloride becomes hygroscopic. The constant difference in maximum and minimum of 9 F and the prevalence of average humidities above 75% show that during most days in the

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\* All with Central Electrochemical Research Institute, Karaikudi, India.



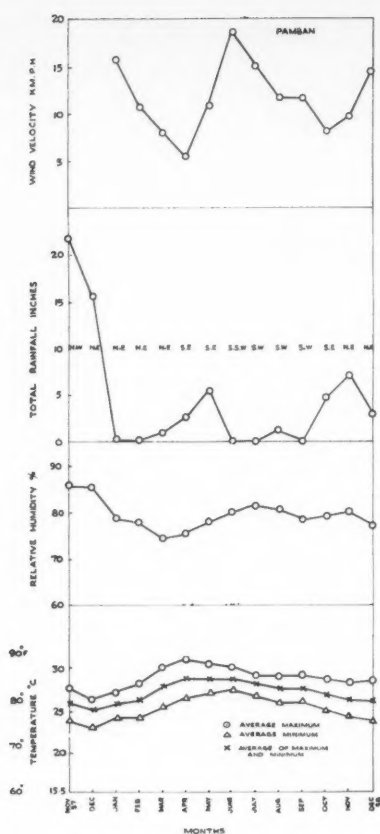


Figure 2—Year's cycle of climatic conditions at Mandapam Camp.

TABLE 1—Climatic Conditions at Pamban Compared With Two Tropical Testing Stations

Station	Average Temp. °F		Average RH (%)	Total Rain (in)
	Max.	Min.		
Lighthouse				
Beach, Lagos...	87	77	86	17.8
Christobal...	84	77	82	130
Pamban...	85	79	80	49*

\*Nov. 57—Oct. 58.

TABLE 2—Monthly Rate of Corrosion of Mild Steel

Months	Rate of Corrosion in gm/sq dm			
	1350-ft Site (hillock)		150-ft Site (shore)	
	Sheltered Exposure	Open Exposure	Sheltered Exposure	Open Exposure
November, 1957	0.065	0.27	.....	.....
December, 1957	0.085	0.125	.....	.....
January, 1958	0.047	0.09	.....	.....
February, 1958	0.11	0.14	.....	.....
March, 1958	0.06	0.06	0.15	.....
April, 1958	0.23	0.35	2.17	.....
May, 1958	0.33	1.16	0.8	.....
June, 1958	0.26	0.52	0.54	4.57
July, 1958	0.18	0.67	0.52	4.0
August, 1958	0.13	0.55	0.43	3.9
September, 1958	0.17	0.39	0.13	1.84
October, 1958	0.11	0.37	0.1	0.94
November, 1958	0.09	0.16	0.04	0.31

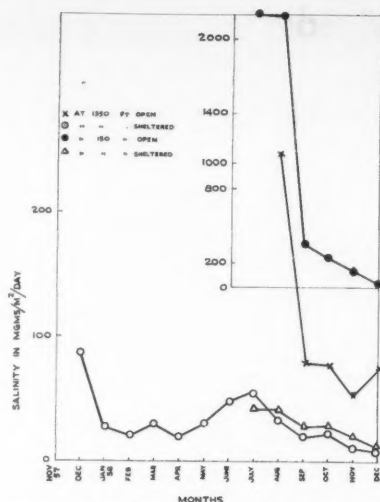


Figure 3—Atmospheric salinity recorded at two sites under sheltered and open conditions.

year there must have been several hours in which moisture condensation was taking place on the metal surface. The period would have been longer during months showing higher average humidity.

The 49 inches of rainfall at this station is distributed within three months during the year under consideration. It is seen that the wind velocity steadily falls during January to April when the northeast monsoon winds which began during the previous year subside and rise to a peak value in June with the onset of southwest monsoon winds. It falls in the subsequent months and again rises when the northeast monsoon winds set in for the year. Climatic conditions at this site are compared with those of Lagos, Nigeria and Christobol, Panama Canal Zone in Table 1. It is readily seen that the conditions at this site bear close resemblance to the other two tropical sites.

#### Atmospheric Salinity at Mandapam Camp

The part played by atmospheric salinity in corrosion at sea coast locations has been extensively considered by Ambler.<sup>2</sup> After investigating various methods for the determination of atmospheric salinity, Ambler came to the conclusion that better correlation could be obtained between salinity determinations made by the wet

candle method and corrosion than in methods where the salt content per cubic meter of air is determined. This method is also more relevant to corrosion studies as it measures the total quantity of salt deposited on a given surface area. He has, however, shown that moisture condensed at the dew point has invariably a high salinity value and shows little variation with distance from sea, the salinity at distances as much as 500 miles from sea being not very different from that obtained on the seashore itself. Thus, under conditions in which dew formation is a daily feature, a simple relationship between salinity and distance from sea may not be obtained. The wet candle method has been employed for the determination of salinity in the present study for the same reasons as pointed out by Ambler.

The variation of atmospheric salinity at the two sites under sheltered and open exposure conditions are shown in Figure 3. It is seen from this figure that a salinity value of 2200 mg/m<sup>2</sup>/day is recorded under open exposure conditions at the shore site in July and August, when the measurements were first made at this site. It falls steeply in September to the comparatively low value of 360 mg/m<sup>2</sup>/day, which further decreases to 38 mg/m<sup>2</sup>/day in December. At the hillock site under open exposure conditions, it is seen that it is approximately 1/10th that at the shore site in August, shows a steep fall in September as in the case of shore site but increases in December when the northeast monsoon winds became strong as shown by the wind velocity data (Figure 2). Under sheltered conditions, the salinity at the two sites is almost the same. This shows that the louvered sides of the Stevenson screen, or for that matter any other barrier, forms a very effective shield limiting the number of salt particles that would otherwise be deposited on the wet candle. Those that are deposited are apparently so fine and so easily carried by wind that they are present in approximately the same extent over a considerable distance from sea. Salinity values obtained at the two sites will then be the same. Variation of salinity figures in different months under sheltered conditions arises from variations in the total quantity of such fine mist in the air. This variation

TABLE 3—Monthly Rate of Corrosion of Zinc

Months	Rate of Corrosion in gm/sq dm			
	1350-ft Site (hillock)		150-ft Site (shore)	
	Sheltered Exposure	Open Exposure	Sheltered Exposure	Open Exposure
November, 1957	0.004	0.05	.....	.....
December, 1957	0.007	0.11	.....	.....
January, 1958	0.002	0.02	.....	.....
February, 1958	0.001	0.005	.....	.....
March, 1958	0.006	0.03	.....	.....
April, 1958	0.002	0.1	0.002	.....
May, 1958	0.01	0.19	0.32	.....
June, 1958	0.02	0.3	0.09	.....
July, 1958	0.04	0.21	0.06	.....
August, 1958	0.04	0.22	0.15	.....
September, 1958	0.18	0.19	0.24	1.05
October, 1958	0.02	0.1	0.01	0.33
November, 1958	0.006	0.13	0.003	0.13
December, 1958	0.002	0.04	0.002	0.04

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will not be as pronounced as in the case of salinity figures obtained under open exposure conditions, which is what has been observed.

#### Rate of Corrosion of Mild Steel, Zinc and Copper

The monthly corrosion rates of mild steel, zinc and copper at the two sites under open and sheltered conditions are given in Tables 2, 3 and 4. It is seen from Table 2 that the monthly corrosion rate of steel reaches a value of 4.57 gm/sq dm at the shore site in the open in July, when a salinity of 2200 mgm/m<sup>2</sup>/day was recorded.

This high corrosion rate is maintained in August and September after which it falls steeply to a value of 0.3 gm/sq dm in December. The monthly corrosion rates of zinc and copper also show a steep fall from September under these conditions. At the hillock site, for which the data are complete for the period under consideration, the corrosion rates in the open are comparatively low and are less than 0.15 gm/sq dm up to May from which month it steeply rises to a peak value of 1.15 gm/sq dm in June. It does not change much during July to September though it is lower than in June. It falls again in October and reaches once again a value of 0.16 gm/sq dm in December. This behavior of steel during the different months appears to be almost completely reproduced by zinc and copper (see Figure 4). Under sheltered exposure conditions, a maximum corrosion rate (2.2 gm/sq dm) is observed at the shore site in May for steel. It falls in the next six months to 0.04 gm/sq dm in December. At the hillock site, where the data are complete, a maximum (0.33 gm/sq dm) is obtained in June as in the case of open exposure but the rise and fall during the period April to September is not so marked. The behavior of copper is similar to that of steel. Under sheltered conditions, the behavior of zinc is somewhat different. At both sites, a sharp rise in the corrosion rate of zinc in September is noticed.

Changes in salinity values during the different months under study have been considered earlier. They do not follow the changes in corrosion rates under open exposure conditions as closely as Ambler's data indicate. The higher salinity values during December 1957 and December 1958 are not reflected in the corrosion rates of steel at the hillock site, for which both data are available. The sharp fall in salinity at the two sites between August and September is not reflected in the corrosion rates of any of the metals studied. The proportionality between salinity, distance from sea and corrosion rate appears to be observed only in July. Under sheltered conditions, it is seen that the salinity values at the two sites do not differ significantly for the months for which these data are available for both sites. Yet, corrosion at the two sites differs considerably, with specimens at the shore site corroding faster.

There is, however, some similarity be-

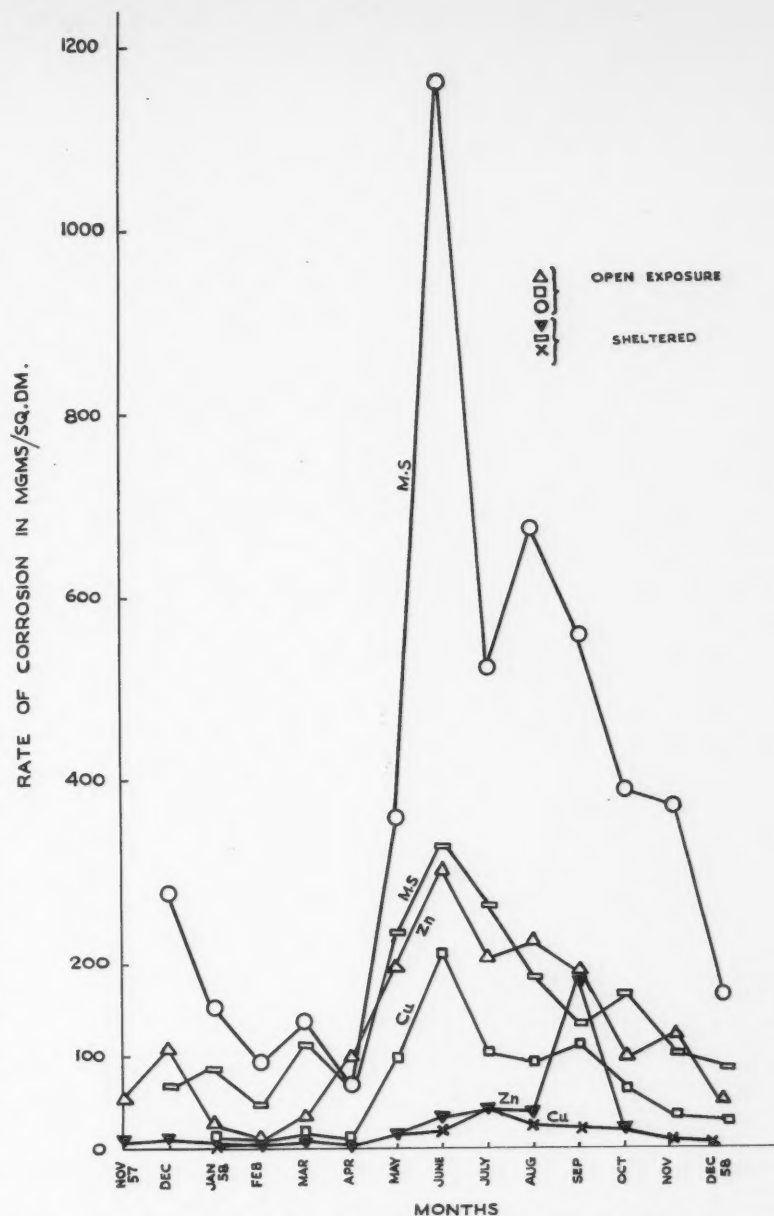


Figure 4—Rates of corrosion of mild steel, zinc and copper, by months, under sheltered and open exposure conditions at 1350 ft. site.

TABLE 4—Monthly Rate of Corrosion of Copper

Months	Rate of Corrosion in gm/sq dm			
	1350-ft Site (hillock)		150-ft Site (shore)	
	Sheltered Exposure	Open Exposure	Sheltered Exposure	Open Exposure
November, 1957.....	.....	.....	.....	.....
December, 1957.....	.....	.....	.....	.....
January, 1958.....	0.003	0.01	.....	.....
February, 1958.....	0.001	0.01	.....	.....
March, 1958.....	0.003	0.013	.....	.....
April, 1958.....	0.002	0.006	.....	.....
May, 1958.....	0.01	0.09	.....	.....
June, 1958.....	0.03	0.21	.....	.....
July, 1958.....	0.035	0.1	.....	.....
August, 1958.....	0.02	0.09	.....	.....
September, 1958.....	0.015	0.11	0.02	0.31
October, 1958.....	0.016	0.06	0.01	0.14
November, 1958.....	0.007	0.02	0.005	0.07
December, 1958.....	0.003	0.015	0.003	0.03

**TABLE 5—Quarterly and Yearly Corrosion Rates of Metals at Mandapam Camp**  
(1350 Ft. From Sea)

Metals	Rate of Corrosion in gms/sq dm									
	January 58-March 58		April 58-June 58		July '58-September '58		October '58-December 58		1958 Yearly	
	Sheltered Exposure	Open Exposure	Sheltered Exposure	Open Exposure	Sheltered Exposure	Open Exposure	Sheltered Exposure	Open Exposure	Sheltered Exposure	Open Exposure
Mild Steel.....	0.24	0.36	0.29	1.56	0.84	1.7	0.61	0.76	1.12	7.17
Zinc.....	0.01	0.04	0.03	0.45	0.04	0.45	0.02	0.12	0.16	0.48
Copper.....	0.004	0.03	0.05	0.31	0.11	0.33	0.035	0.066	0.42	0.7

tween the salinity curve and the corrosion curve at the hillock site especially for the period April to September. Ambler concluded from his study of corrosion along the seacoast in Nigeria that salinity is the determining factor in the corrosion of metals in the tropics. Data collected at Mandapam Camp indicate that while salinity is undoubtedly an important factor in determining corrosion rate under high salinity conditions, its effect can become overshadowed by weather conditions. In this connection, the work of Ellis<sup>10</sup> on the part played by weather conditions at the time of initial exposure in determining the corrosion rate of zinc and Larrabee's<sup>11</sup> observation that weather conditions should also play a part in determining the rate of corrosion of steel has much interest to this work.

Results given in this paper clearly bring out the important role played by weather conditions. A maximum is reached in the case of every metal considered at both sites during those months when the weather conditions represented by humidity and mean temperature values as well as atmospheric salinity are most propitious for increased corrosion. While considering the meteorological data, it was pointed out that the constant difference in maximum and minimum temperature values and the existence of humidities higher than 75 percent during most months indicate that in the months in which higher average humidity values are recorded, it is probable that moisture condensation periods due to temperature gradients also are longer. Field studies in the United States have shown that the duration for which moisture condensation takes place is an important factor governing the corrosion rate.<sup>12</sup> Maximum corrosion rates at the present site are observed only during June to August, though humidities similar to those occurring during those months also are recorded during October to December. The increase in corrosion rate in June is much greater under open exposure conditions when the metal specimens are directly exposed to sunlight than under sheltered exposure conditions. The important part played by a small increase (7 F) in ambient temperature in the enhancement of the corrosion rate at this site is thus brought out.

It was mentioned earlier that there is an increase in the corrosion rate of zinc in September at both sites which is not readily understood. It is probably related to the air becoming stagnant under sheltered conditions when the southwest wind stops blowing and the northeast wind has not started. That this is so is indicated by the steep fall in salinity values between August and September at both sites as well as wind velocity data.

Experiments carried out in this laboratory have shown that under restricted circulation of air flow, the rate of corrosion of zinc increases sharply<sup>13</sup> at high humidities. A considerable increase in white rust formation on zinc under storage conditions also was noticed during the last war.<sup>14</sup>

The quarterly and yearly corrosion rates at the hillock site for which the data are complete are given in Table 5. It may be seen from this table that the pattern of corrosion indicated by the monthly data are corroborated by the quarterly data for the same periods. The corrosion rate is highest during the period July-September in the case of all the metals and least during January-March. The data also show that the year can be conveniently divided into two periods April-September and October-March, the corrosion rate of steel in the former period being three times that during the latter under open exposure conditions. An average corrosion rate of 0.6 gm/sq dm/month under open exposure conditions and 0.09 gm/sq dm/month under sheltered conditions are recorded at this site.

### Conclusions

1. It has been shown with the help of meteorological data and monthly corrosion data for mild steel, zinc, copper and aluminum that very high corrosion rates comparable to those obtained at Lighthouse Beach, Lagos are obtained at the Mandapam Camp Testing Farm and that this test farm is, hence, eminently suitable for testing under tropical marine conditions.

2. There is no direct relationship between corrosion rate, distance from sea and atmospheric salinity as determined by the wet candle method, as pointed out by Ambler. Salinity is, however, found to be an important factor in de-

termining the corrosion rate under open exposure conditions.

3. A small increase in mean temperature causes considerable acceleration in the corrosion rate in the open when accompanied by both high humidity and salinity. The highest corrosion rates are observed in the months in which high mean temperature is accompanied by high average humidity and high salinity.

4. While there are some variations in the behavior of steel and zinc under similar conditions, the behavior of steel is paralleled by both zinc and copper though at lower corrosion rates. Copper appears to be more suited among non-ferrous metals for the study of atmospheric corrosivity at sea-coast locations.

### Acknowledgment

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# Polyester Fiber Glass Equipment\*

By ROBERT E. BARNETT and THOMAS F. ANDERSON

## Introduction

TO MAKE data contained in this article representative of the wide use of polyester fiber glass equipment in the chemical, petroleum and allied industries, all major producers of corrosion resistant polyester fiber glass equipment were written to in the summer of 1958. A request was made for information they would like to have included in this article, to include pictures of the equipment, descriptions of construction, time at which the equipment was installed, service conditions to which subjected and conditions now. Pictures and case histories included in this article consist of contributions from Corite Products, Inc., duVere, Inc., Schori Process Division of Ferro Corporation, and Haveg Corporation. All of those contributing pictures and service histories found it difficult to get current information on the condition of some items. The authors will appreciate being advised of incorrect information herein.

Over 200 commercially available polyester resins have been screened in the Haveg laboratories to determine their usefulness in corrosive applications. While most differ in varying degrees from others, it is possible to group all of them into five broad categories:

- Highly chemical resistant ..... Type A
- Medium chemical resistant ..... Type B
- Standard chemical resistant ..... Type C
- Food grade and solvent resistant ..... Type D
- Fire resistant, chemical resistant ..... Type E

Because large differences exist in the ability of different polyesters to resist chemical attack, it is important that the right polyester resin be chosen for an application. Also, because proper construction and cure are essential for good quality, it is important to select a qualified fabricator.

## Resistance Table Provided

To assist in the selection of the proper type of polyester for a chemical application, chemical resistance tables with over 5,000 ratings are given in the appendices. These tables were compiled over a 5-year period from a combination of laboratory tests and field service information. At the beginning of the first table is a discussion explaining suggested methods of using the table. It will be noticed that the ratings in this table are broken down into recommendations for tank



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service and recommendations for use in open hoods and connecting ductwork. Proper ratings for systems of closed hoods and closed-connection ductwork normally would fall in between the ratings shown for tanks and for open hoods. The data in this table are, of course, subject to revision as additional field information becomes available. Any having service information on polyester fiber glass equipment which will extend or amend this table are urged to send it to the authors.

It has been found that polyester fiber glass structures are more rapidly attacked by corrosive environments when highly stressed, so it is particularly important to use proper construction in fabrication. Table 1 shows some representative properties of different constructions frequently used in the manufacture of chemical resistant equipment. Experience has now shown that a minimum of 5 to 1 safety factor over the measured physical properties of polyester fiber glass laminates is required in the design of equipment which will continue to give long, satisfactory service. As service conditions become more severe, both with regard to temperature and to corrosive characteristics, it is necessary to increase this safety factor to as much as 12 or 15 to 1.

In the discussion which follows, equipment is divided into classes, with the pictures of several units in each class. The equipment and the specific service conditions are described.

## Abstract

Polyesters used in situations where their chemical resistance is important are grouped into five types for convenience in considering their value under attack by industrial corrosives at varying temperatures. Data were compiled from information supplied by four of the major producers on polyester ducts, hoods and tanks as were 17 illustrations of equipment. Pictured equipment is described, environment indicated and durability reported. Corrodents involved include sulfonated fish oil, acidified oils, HCl containing benzene, nitric acid, hydrochloric acid and fumes, plating solutions, sulfuric acid and others at varying temperatures. Some of the characteristics of and reasons for using lined equipment are given.

The appendix consists of four tables in which polyesters are rated for service as open hoods and connecting ductwork and for tanks against a wide variety of industrial corrosives, plating solutions pickling and dipping solutions and stripping solutions. Over 5000 ratings are given as excellent, good, fair, poor and not recommended at temperatures of 80 F or less, 212 F or boiling point of solution, if lower; 160 F, 180 F. 6.68

## Uses for Lined Equipment

Occasionally for tanks, towers, covers, hoods, stacks and fume scrubbers, because of the rigidity required or because available equipment has sufficient strength but insufficient chemical resistance, it becomes economical to use polyester fiber glass lined equipment.

Because only the linings have corrosion resistance that solid polyester fiber glass tank has, the chemical resistance rating for a lining would fall somewhat below that given in the appendix. In general, in tank sizes in excess of 20,000 gallons, where the lined tank will satisfactorily handle the chemical applications, a cross-over point is reached in the economic considerations. In the construction of rectangular tanks, because of the high cost of stiffening the sides, or because of mechanical loads, linings sometimes are more economical for even small tanks.

The wall of a 55-foot diameter x 12-foot deep, 200,000 gallon concrete tank after three years' service in 37 percent formaldehyde at 80-90 F in some areas had been eaten away as deeply as 6 or 7 inches and extensive repairs were required before application of a polyester fiber glass lining. Figure 22 shows this tank after being lined with polyester fiber glass. The tank shows no sign of attack after almost two years.

The extensive history now available on the use of polyester fiber glass equipment in the chemical, petroleum and allied industries, includes reports of an impressive array of successes and also examples of failures. Information gathered underlines the need for selection of the proper polyester and of putting polyester fiber glass constructions into the areas where they are best suited. It would appear that, based on the economics, greater use of polyester fiber glass equipment seems to be justified.

Many misunderstandings and misconceptions about polyester fiber glass equipment have been, or are being corrected, for example:

1. It no longer is the belief that the term 'polyester fiber glass' denotes one material. It is generally realized that the term denotes a family of materials with widely differing properties, so, all poly-

\* Submitted for publication February 27, 1959. A paper presented at the Fifteenth Annual Conference, National Association of Corrosion Engineers, Chicago, Ill., March 16-20, 1959.

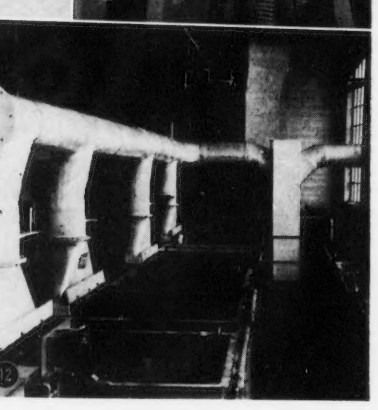
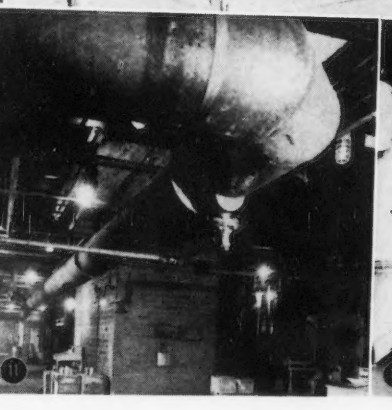
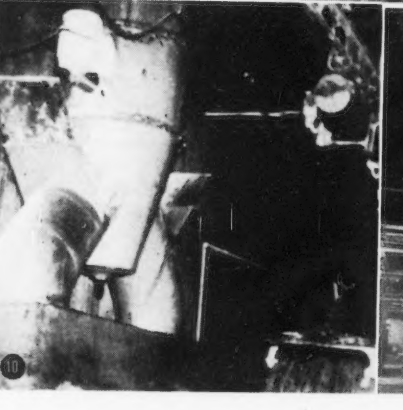
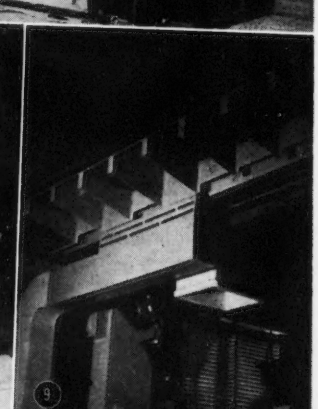
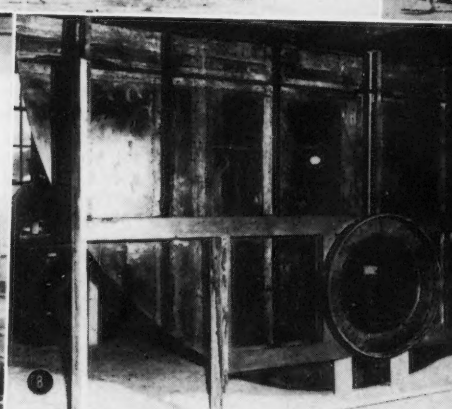
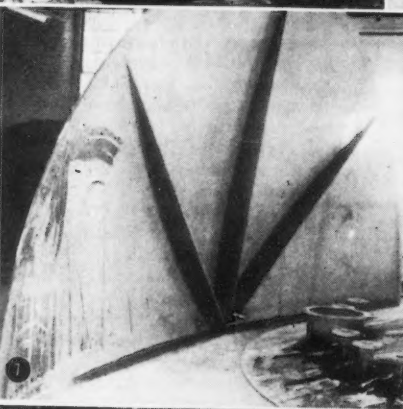
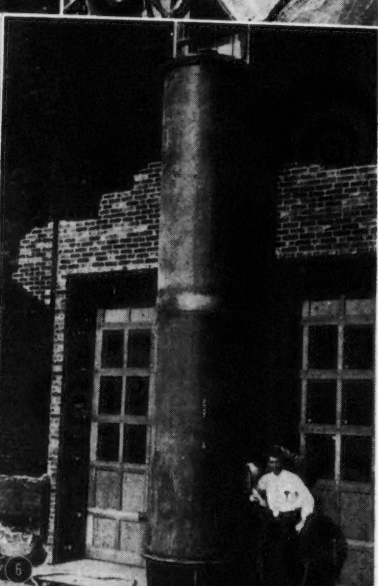
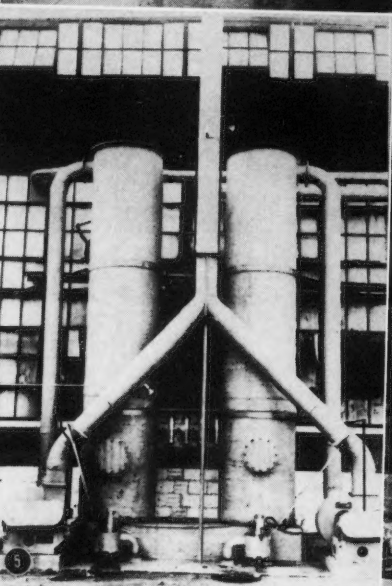
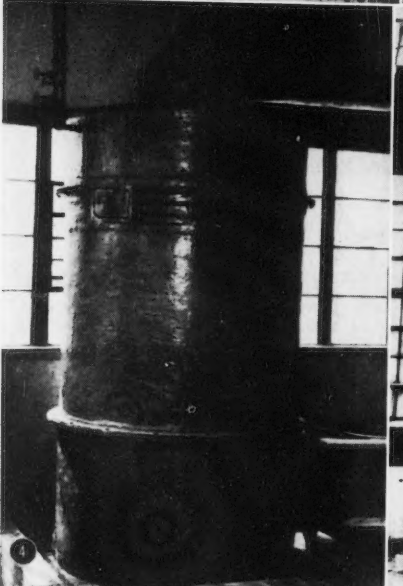
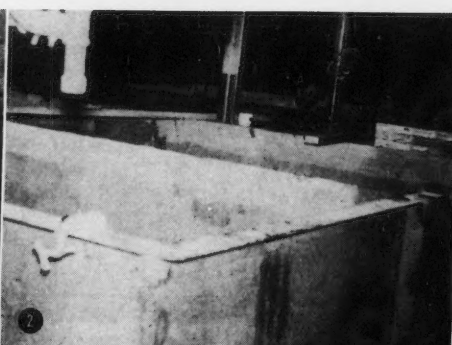
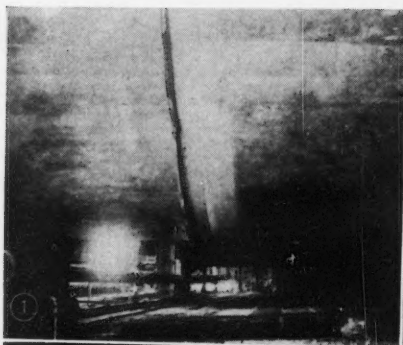


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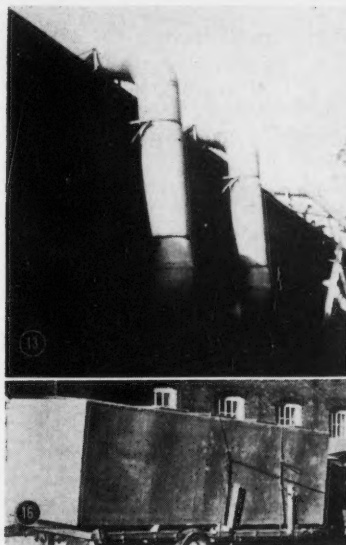


Figure 1—Cylindrical tank, 10 x 10 feet, polyester fiber glass, 5-1 safety factor, 160 F. Neutralization of sulfonated fish oils. Violent agitation. Installed Nov. 1953, no sign of attack after 5½ years, still translucent.

Figure 2—Rectangular tank, 10 x 14 x 4 feet deep. Polyester fiber glass sheet lined steel. Built-in foam rubber expansion strips allow for differential. 150 F washing of acidified oils. Installed Feb. 1954, no attack after 5 years.

Figure 3—Cylindrical tank, 12 D x 17 feet, polyester fiber glass. Storage byproduct HCl containing benzene, 120-180 F. Outdoors, Southwest USA, installed Sept. 1956, no attack after 2½ years; some external discoloration.

Figure 4—Fume scrubber, tower 5 D x 10 feet, Raschig rings and support plates all of polyester fiber glass. 6500 cfm HNO<sub>3</sub> fumes and air. Incoming air approx. 200 F. Installed Aug. 1956, no sign of attack after 2½ years.

Figure 5—Fume scrubbers packed towers. 42 inches D x 16 feet, polyester fiber glass. Interchangeable scrubbing of HCl and NH<sub>3</sub>. No visible fumes in mixed effluent. Installed May 1956, no sign of attack after 2¾ years.

Figure 6—Fume scrubber, 3 D x 15 feet, polyester synthetic lined polyester fiber glass. Scrubbing HF fumes. Installed April 1955, condition excellent after 4 years.

Figure 7—Cover 23-foot diameter, dished, made in two sections for shipping, polyester fiber glass. Room temp storage HCl. Installed Jan. 1957, condition excellent after 2 years.

Figure 8—Cover, flat, uncured, ribbed, approx., 14 feet D. Supports wooden stack with steel ribs, polyester fiber glass. Magnesium chloride reactor, installed 1958, condition unknown.

Figure 9—Hoods and tank, polyester fiber glass. Precious metal plating, temp. ambient to 200 F. Installed Dec. 1954, condition excellent after over 4 years.

Figure 10—Hood and fan. Hood 22-foot, undraft fan 36 D propeller type, polyester fiber glass. Fumes from 6% H<sub>2</sub>SO<sub>4</sub> at 212 F. Installed Dec. 1955, condition excellent after over 3 years.

Figure 11—Ductwork, 24-inch, polyester fiber glass. Replaced Monel duct that failed in two years. Vapors from oleum quench containing approx. 30% H<sub>2</sub>SO<sub>4</sub>. Installed 1954, condition excellent after 5 years.

Figure 12—Ductwork, 12 to 18 inches, polyester fiber glass. Removal of wide variety pickling and plating solution fumes. Installed 1954, condition excellent after 5 years.

Figure 13—Ductwork, 30-inch, polyester fiber glass. Vapors from warm acid drip; H<sub>2</sub>SO<sub>4</sub> and HCl at 140-160 F. Installed July, 1954, condition excellent after 5 years.

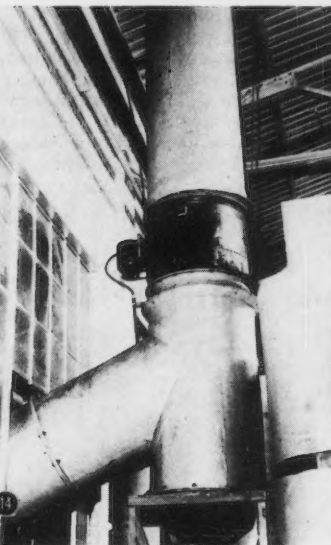


Figure 14—Stack, 30-inch, polyester fiber glass. Fumes from 4% and 12-15% HNO<sub>3</sub> at 115 F. Installed July, 1954, condition excellent after 5 years.

Figure 15—Stack, 5, 6 and 7½-foot x 80 feet polyester fiber glass lined steel. Removal of fumes in refining of fissionable material. Installed Oct., 1957, condition excellent after 1½ years.

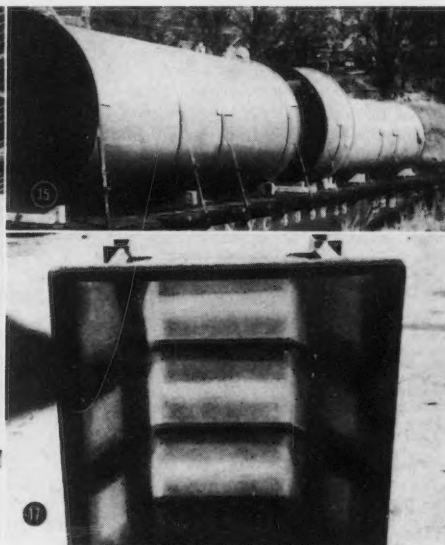


Figure 16—Fume scrubber, 7 x 7 x 18 feet, polyester fiber glass. Scrubbing fumes from wire pickling line. Installed Dec., 1956, condition excellent after over 2 years.

Figure 17—Press box, 4 x 4 x 18 feet, polyester fiber glass and steel. Storage and handling acid-containing dye cake at temp. up to 180 F. Installed Nov. 1956, condition varied from excellent to charred in cases when sulfuric acid concentration exceeded 90 percent.

**TABLE 1—Physical Properties of Polyester Fiber Glass Laminates and Cold Rolled Steel**

STRENGTH PROPERTY	CHOPPED STRAND MAT 20% glass 80% poly.	COMPOSITE CONSTR.	PLAIN WEAVE WOVEN ROVING NON ORIENTED 55% glass	2-1 ORIENTED WEAVE WOVEN ROVING 55% glass tested in strongest direction	PLAIN COLD ROLLED STEEL
TENSILE P. S. I.	8,000	8,000 to 30,000	21,000	30,000	30,000-50,000
COMPRESSIVE P. S. I.	30,000	30,000	30,000	30,000	30,000-50,000
FLEXURAL P. S. I.	14,000	14,000 to 30,000	24,000	30,000	30,000-50,000
FLEXURAL MODULUS P. S. I.	7 x 10 <sup>5</sup>	7 x 10 <sup>5</sup> to 2.5 x 10 <sup>6</sup>	1.5 x 10 <sup>6</sup>	2.5 x 10 <sup>6</sup>	30 x 10 <sup>6</sup>
INTER-LAMINAR SHEAR STRENGTH P. S. I.	2,000	2,000	1,800	1,800	20,000-40,000
% OF ULTIMATE TENSILE COMPRESSIVE & FLEXURAL STRENGTHS which can be carried as long term load	20 %	20 %	20 %	20 %	> 80 %
% OF ULTIMATE SHEAR FOR LONG TERM LOAD	50 %	50 %	50 %	50 %	> 80 %



ester fiber glass is not condemned because one grade has failed.

2. Experience has shown that polyester fiber glass equipment, of the right compositions and properly handled, weathers extremely well.

Great advances are being made in improving physical and chemical properties of the polyester resins. For instance, chemical resistant polyester resin is far

superior now in toughness to those available only a few years ago. While progress in resin chemistry perhaps has been on a plateau, resins with better chemical resistance are in the development stage. Substantial advancements also are being made in reinforcements and fillers which will improve the over-all properties. Expanding uses of reinforced polyesters in the corrosion resistant field can be expected.

When considering the use of reinforced plastics keep in mind:

**First.** Use them where their high strength and light weight, coupled with corrosion resistance, recommend their use.

**Second.** Get help from a competent company in selecting plastic materials.

**Third.** Do not consider them as cheap substitutes. Make sure equipment is properly designed and made.

## Ratings of Polyester Hoods, Ducts and Tanks vs Industrial Corrosives

Data in this table have been compiled by correlating laboratory test data with information available from field test results. Because exact conditions seldom are duplicated from one situation to another, it is suggested that in cases where there is reason to believe the application may be borderline, a special field test be made for reliable evaluation. While data in the table were compiled on specific polyester resin compositions, these fall into the following classes:

Highly chemical resistant polyester.....Type A  
Medium chemical resistant polyester.....Type B  
Standard chemical resistant polyester.....Type C

Food grade and solvent resistant polyester.....Type D  
Fire resistant, chemical resistant polyester.....Type E  
Note. Although ratings on Type E are not given in the table, in general, chemical resistance of this grade of material falls between Type B and Type C, with some exceptions.

Interpretations of the symbols used in the ratings given in the table are as follows: Cold—80 F or less; Hot—212 F or boiling point of solution, if lower; E—Excellent, no attack; G—Good, no appreciable attack; F—Fair, slight attack; P—Poor, definite attack, use only in special cases; NR—Not recommended.

## APPENDIX

### Ratings of Polyester Hoods, Ductwork and Tanks vs Industrial Corrosives

Open Hoods and Connecting Ductwork*												Tanks											
Type A			Type B			Type C						Type A			Type B			Type D					
Cold	160 F	Hot	Cold	160 F	Hot	Cold	160 F	Hot	Corrodent			Cold	160 F	Hot	Cold	160 F	Hot	Cold	160 F	Hot	Cold	160 F	Hot
E	E	E	E	E	E	E	E	P	Acetic Acid.....	10	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	.....	25	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	.....	75	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Acetone.....	25	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Acrylonitrile.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Alcohol, Amyl.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Benzyl.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Butyl.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Ethyl.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Methyl.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Aluminum chloride in ethanol.....	25	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Aluminum potassium sulfate.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Aluminum sulfate.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Ammonia, aqueous.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Ammonium bicarbonate.....	100	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Ammonium carbonate.....	10	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	.....	100	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Ammonium chloride.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Ammonium hydroxide.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Ammonium nitrate.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Ammonium persulfate.....	10	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Ammonium sulfate.....	25	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Ammonium sulfite.....	10	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Aniline sulfate.....	10	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Antimony trichloride.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Barium carbonate.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Barium chloride.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Barium hydroxide.....	10	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Barium sulfide.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Benzaldehyde.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
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E	E	E	E	E	E	E	E	P	Butyl acetate.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
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E	E	E	E	E	E	E	E	P	.....	100	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Calcium chloride.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
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E	E	E	E	E	E	E	E	P	Calcium sulfate.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Carbon disulfide.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Carbon tetrachloride.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Chlorine dioxide bleach.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Chlorine gas, dry.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Chlorine water, saturated.....	50	E	E	F	E	G	P	E	E	F	E	E	F	F
E	E	E	E	E	E	E	E	P	Chloroacetic acid.....	10	E	E	F	E	G	P	E	E	F	E	E	F	F

\* Ratings for closed hoods and connecting ductwork fall between ratings for tanks and ratings for open hoods and connecting ductwork.

## APPENDIX (continued)

Open Hoods and Connecting Ductwork*									Corrodent	Conc. %	Tanks								
Type A			Type B			Type C					Type A			Type B			Type D		
Cold	160 F	Hot	Cold	160 F	Hot	Cold	160 F	Hot			Cold	160 F	Hot	Cold	160 F	Hot	Cold	160 F	Hot
E E E E E	E G G G E	G F F F E	E E E E E	G G F G E	F P P P G	E G F E E	F P P G G	P P P P P	.....	25 50 100	E G F E	G F P E	F F N R F	E G P F E	G F N R P	F P N R P	E G F E	G F N R P	F P N R P
E E E E E	E E E E E	E G G G E	E E E E E	E E E G E	G G F G	E E E E E	G G F G	P P P P F	.....	5 10 20 30	E E E E	G F F E	F F P P G	E E G E	G F P G	P P P N R F	E E E G E	G F P G	P P P N R F
E E E E E	E E E E E	E E E E F	E E E E E	E E E G F	G G F P	E E E E E	G G F G	F P F P F	Copper chloride.....	...	E E E E	E E E G	G G G G N	E E G F	G G G P	F F F F N	E E E E G	G F G G F	P P P G N
G E G E E	F G F E E	P F P E E	G G F E E	F F P E E	P P P G G	G G F E E	F F P G G	P P P P F	Dimethyl phthalate.....	...	F G F E	P F P E	N R P N R G	F F P E	P P N R	N R N R F	G G G E	F F P F E	N R P N R P
E E E G E	E E E F E	E E E P E	E E E G E	E E E F E	G G G P G	E E E G E	G G P G	F F F N R	.....	50 75 100	E E E N	E E E N	E E E N	E E E N	E E E N	G G G N	E E E P E	E E E P E	E E E N G
E E E E E	E E E E E	E E E E E	E E E E E	E E E E E	G G G G G	E E E E E	G G G G G	F F F F F	Ferric chloride.....	...	E E E E	E E E E	G G G G	E E E E	G G G G	F F F F F	E E E E E	G G G G G	P P P P P
E E E E G	E E E E E	E E E E E	E E E E E	E E E E E	G G G E G	E E E E G	E E G E	G F F F	Formaldehyde.....	10 25 37 25 50	E E E E E	E E E E	.....	E E E G	G G G	.....	E E E E E	E E E E E	.....
E E G E E	G G P E E	P P N R E	E E G E E	F F P E E	N R N R E	E E G E E	F F P E E	N R N R G	Furfural.....	5 10 100	E E F E	F F N R	N R N R E	G G P E E	P P N R	N R N R G	E E F E E	F F N R E	N R N R E
E E E E E	E E E G E	E G G F E	E E E E E	E E E G E	G G F G	E E E E E	E G G G	G F F P	Heptane.....	10 20 37 10	E E E E	E G G F	E F P P	E E E E	E G G P	G P P P	E E E E E	E F F P	E P P N R
E E E E E	E G G E E	.....	E E E E E	E G E E	.....	E E E G E	F F P F	.....	Hydrogen peroxide.....	3 10 30	E E E E	G F .....	.....	E E E E	G F .....	.....	E G F G E	F P .....	.....
E E E E E	E E E E E	E E E E E	E E E E E	E G E E	G G G G	E E E G E	F F F G	F .....	Hypochlorite bleach.....	...	E E E E	G E .....	P G	E E E E	G G F	P F	E E E E E	G F G E	N R F
E E E E E	E E E E E	E E E E E	E E E E E	E E E E E	G G G G	E E E E E	G G G G	F F F F	Lead acetate.....	...	E E E E	E E E E	G F G G	E E E E	G F G G	F F F F	E E E E E	G G F G	P P P P P
E E E E E	E E E E G	E E E E E	E E E E E	E E E G F	G G E E	E E E E E	G G G F	F F F E	Maleic acid.....	10	E E E E	E E G P	G G N R	E E P	F G G N	P F F N	E E E E F	F G G P	P P P N R
E E E E E	E E E E E	E E E E E	E E E E E	E E E E E	G G G G	E E E E E	E G G G	G F F	Naphtha.....	...	E E E E	E E E E	E G G P	E E E E	E G G F	E F F P	E E E E E	E G G P	E P P N R
E E E E G	G G E E F	F F E E P	E E E E G	G G E E P	F F G G P	G G E E G	F F G G P	P P F P	Nickel chloride.....	10 20	G F E E	P F E P	P N G G N	G F G E P	P P G N	N R F F N	F F E E E	P N E G P	N R N R E
E E E E E	E G G E E	E P P E E	E E E E E	E G P E E	G P P G G	E E E E E	G P P G G	F P P F	Oxalic acid.....	...	E E E E	F F E E	P N R G	F G E E	P P G G	N R N R F	E E E E E	P F F G	N R N R P
E E G E E	E P P E E	E N R N R	E G F E E	E P P E E	G N R G G	E P P E E	G N R G	F N R	Phosphorus oxychloride.....	85	E G N R	E N R	G N R G	E F N R	G N R F	F N R F	E G F E E	G N R G	F N R F
E E E E E	E E G G E	E E E E E	E E E E E	E E E G E	G G G G	E E E E E	E F F G	P P P P	Phthalic anhydride.....	100	E E E E	G F F E	P P P N	E E E E	G G F P	E E G F	E G G E	F P N R	N R N R P
E E E E E	E E E G G	G E E F F	E E E E E	E E E G F	G G G P	E E E F F	G G P P	F F N R	Potassium bicarbonate.....	...	E E E G	E E E F	G G N R	E E G F	G G P P	F F N R	E E E F	G G N R	P P P N R
E E E E E	E E E G G	E E E E E	E E E E E	E E E E E	G G G G	E E E E E	E F F G	P P P P	Potassium carbonate.....	100 10 25 100	E E E E	G F F E	P P P N	E E E E	G G F P	P P P N	E E G F	F P N R	N R N R P
E E E E E	E E E G G	E E E E E	E E E E E	E E E G F	G G G P	E E E F F	G G P P	F F N R	Potassium chloride.....	...	E E E G	E E E F	G G N R	E E G F	G G P P	F F N R	E E E F	G G N R	P P P N R

\* Ratings for closed hoods and connecting ductwork fall between ratings for tanks and ratings for open hoods and connecting ductwork.

## APPENDIX (continued)

Open Hoods and Connecting Ductwork*									Corrodent	Conc. %	Tanks								
Type A			Type B			Type C					Type A			Type B			Type D		
Cold	160 F	Hot	Cold	160 F	Hot	Cold	160 F	Hot			Cold	160 F	Hot	Cold	160 F	Hot	Cold	160 F	Hot
E E E E E	G E E E E	P E G G E	E E E E E	F E E E E	P G G G G	F E G G E	P G F F G	NR F P P P	Potassium nitrate Potassium permanganate Potassium persulfate Potassium sulfate	50 ... ... ...	G E E E E	P E E E E	NR G G G G	F E E E E	P G G G G	NR F F F F	P E E E E	NR G G G G	NR P P P P
G E E E E	P E E E E	NR E E G E	F E E E E	P E E E E	NR G G G G	P E E E E	NR G G G G	NR F F F F	Pyridine Silver nitrate Sodium acetate Sodium bicarbonate Sodium bisulfate	... ... ... 10 ...	NR E E E E	NR E E E E	NR G G G G	NR E E E E	NR G G G G	NR F F F F	NR E E E E	NR G G G G	NR P P P P
E E E E E	E E E E E	E G E G E	E E E E E	E E E E E	G G E G G	E E E E E	G F E F G	F P P P P	Sodium bisulfate Sodium carbonate Sodium chloride	... 10 25 100 10	E E E E E	E F F F E	G P P P G	E E E E E	G F P P G	F P P NR F	E G F F E	G F P NR G	P P NR NR P
E E E E E	E E E G G	E E E F P	E E E E E	E E E G F	G G F P P	E E E F P	G G P NR P	F F F NR NR	Sodium ferrioxalate Sodium hydroxide	25 100 10 25 50	E E E G F	E E E P P	E E NR NR	E E G F	G P P P	F G NR NR	E E P P P	G E NR NR	F G NR NR
E E E E E	E E E E E	G G E E E	E E E E E	E E E E E	G G G G G	G G E E E	F F F G G	... ... F	Sodium hypochlorite Sodium nitrate Sodium nitrite	5 10 15 ...	E E E E E	G G E E E	P ... G G	E E E E E	P G G G	F F F F	G G E E	F F G G	P ... P P
E E E E E	E E G G E	E F F F G	E E E E E	E E G G G	G F F F E	E E G G E	G G F F G	F F P P P	Sodium sulfate Stearic acid Sulfur dioxide Sulfur trioxide Sulfuric acid	... ... ... ... 10	E E E E E	E E E E E	G E E E G	E G G G P	F F F P E	E E E E E	G E E E F	E E E E P	P E ... ... P
E E E E E	E E E E G	G E G F E	E E E E E	G E E E F	F E G F P	E E E G F	G G F P P	P P F P P	...	20 25 30 60 70	E E E E G	E E E G F	F F G F P	E E G G E	G G G P P	P F F E F	E E E E E	F F G G G	P P F NR P
G E E E E	F E P E P	P G P E NR	G E G E E	F G P E P	P F P G NR	P G E E G	NR G P G P	NR P NR F NR	Sulfuric acid, fuming Sulfuric acid, pickling Styrene monomer, inhibited Tartaric acid Tetrachloroethane	... ... ... ... ...	NR E G E G	NR E NR E NR	NR G NR E NR	NR E G E ...	NR P G F ...	NR E E E E	NR F NR G NR	NR P NR NR NR	
E E E E E	G E E G E	P G G F E	G E E E E	F E E G E	P G F E G	G G F E E	P F F P G	NR P P NR F	Toluene Trisodium phosphate Water	... 10 25 50 100	G E E G E	F F F F E	NR P P NR G	F E E E P	P F F P G	NR P P NR F	G G G F E	F F P NR G	NR P NR NR P
E E	E E	E E	E E	E E	G G	E E	G G	F F	Water vapor Zinc sulfate	100 ...	E E	E E	G G	E E	G G	F F	E E	G G	P P

## Appendix 2—Polyesters vs Metal Finishing Plating Solutions

Open Hoods and Connecting Ductwork*						Application and Corrodent	Tanks			
Type A		Type B		Type C			Type A		Type B	
Cold	180 F	Cold	180 F	Cold	180 F		Cold	180 F	Cold	180 F
E	E	E	E	E	P	Brass Plating 3% Cu(CN) <sub>2</sub> , 0.94% Zn(CN) <sub>2</sub> , 5.6% NaCN, 3% Na <sub>2</sub> CO <sub>3</sub> .....	E	G	E	P
E	E	E	G	E	F	Bright Nickel (Harshaw).....	E	G	E	F
E	E	E	E	E	P	Bronze Plating 4.13% Cu(CN) <sub>2</sub> , 5.1% NaCN, 3% Na <sub>2</sub> CO <sub>3</sub> , 4.5% Rochelle Salts.....	E	G	E	F
E	E	E	E	E	F	Copper Plating 44.8% Cu(BF <sub>4</sub> ) <sub>2</sub> ..... Acid: 19% CuSO <sub>4</sub> · 5H <sub>2</sub> O, 8.3% H <sub>2</sub> SO <sub>4</sub> .....	E	G	E	F
E	E	E	E	E	P	Copper Cyanide, Rochelle Salts Bath 10.5% Cu(CN) <sub>2</sub> , 14.3% NaCN, 6% Rochelle Salts.....	E	G	E	F
E	G	E	G	F	P	Cyanide Zinc Barrel Plating 9% Zn(CN) <sub>2</sub> , 4.2% NaCN, 9% NaOH.....	G	P	G	P
E	E	E	E	E	F	Iron Plating 45% FeCl <sub>2</sub> , 15% CaCl <sub>2</sub> ..... 20.3% FeSO <sub>4</sub> · 7H <sub>2</sub> O, 10.5% (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub> .....	E	G	E	G
E	G	E	F	F	P	Lead Plating, Alkaline 7.5% Pb(C <sub>2</sub> H <sub>3</sub> O <sub>2</sub> ) <sub>2</sub> , 20% NaOH, 0.5% Rosin.....	G	P	G	P
E	G	E	G	F	P	White Brass Alloy Plating 6% Zn(CN) <sub>2</sub> , 1.1% Cu(CN) <sub>2</sub> , 3.5% NaCN, 5.3% NaOH.....	G	P	G	P

\* Ratings for closed hoods and connecting ductwork fall between ratings for tanks and ratings for open hoods and connecting ductwork.



### Appendix 3—Polyesters vs Pickling and Dipping Solutions

Open Hoods and Connecting Ductwork*							Tanks			
Type A		Type B		Type C		Application and Corrodent	Type A		Type B	
Cold	180 F	Cold	180 F	Cold	180 F		Cold	180 F	Cold	180 F
E	G	E	G	F	P	Alkaline cleaning of metals 6% NaOH, 6% Na <sub>2</sub> PO <sub>4</sub> .....	G	P	G	P
E	E	E	G	G	F	Brass, cleaning 6% Na <sub>2</sub> PO <sub>4</sub> .....	E	F	E	P
E	E	E	G	E	F	Copper and Alloys, cleaning 20% H <sub>2</sub> SO <sub>4</sub> .....	E	G	E	F
E	E	E	G	E	F	Copper Pickling 9.7% Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> , 9.7% H <sub>2</sub> SO <sub>4</sub> , 9% H <sub>2</sub> SO <sub>4</sub> , 1.2% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> · 2H <sub>2</sub> O, 3.6% H <sub>2</sub> SO <sub>4</sub> .....	E	G	E	F
E	E	E	E	E	F	Copper Matte Dipping 29% FeCl <sub>3</sub> , 18.5% HCl.....	E	G	E	F
E	G	E	G	E	F	Iron and Steel, cleaning 6% H <sub>2</sub> SO <sub>4</sub> , 8.5% HCl, 23% H <sub>2</sub> SO <sub>4</sub> .....	E	G	E	F
E	G	E	G	E	F	Magnesium and Alloys, cleaning 18% CrO <sub>3</sub> , 2.25% Na <sub>2</sub> CO <sub>3</sub> · 10H <sub>2</sub> O, 1.5% NaOH.....	E	G	E	F
						Monel, see Nickel				
E	E	E	E	E	F	Nickel and Monel Pickling 2% CuCl <sub>2</sub> , 15% HCl, 8% NaNO <sub>3</sub> , 8% NaCl, 20% H <sub>2</sub> SO <sub>4</sub> .....	E	G	E	F
E	E	E	G	E	F	Nickel and Monel Scale Removal 9.8% Fe <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> , 3.6% HCl.....	E	G	E	F
E	E	E	G	E	F	Nickel-Silver Pickling 3% Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> , 22% H <sub>2</sub> SO <sub>4</sub> .....	E	G	E	F
E	E	E	E	E	F	Silver, see Nickel				
E	E	E	G	E	F	Stainless Steel Scale Loosening, 9% H <sub>2</sub> SO <sub>4</sub> .....	E	G	E	F
E	G	E	G	F	P	Steel Cleaning 6% NaOH, 6% H <sub>2</sub> SO <sub>4</sub> , 50% H <sub>2</sub> SO <sub>4</sub> , 8.5% HCl, 23% H <sub>2</sub> SO <sub>4</sub> .....	G	P	G	P
E	E	E	E	E	F	Zinc and Alloys, cleaning 3% Na <sub>2</sub> SO <sub>4</sub> , 30% CrO <sub>3</sub> .....	E	G	E	F
E	E	E	G	E	F	Miscellaneous cleaning 2.25% HNO <sub>3</sub> .....	E	G	E	F

### Appendix 4—Polyesters vs Stripping Solutions for Salvage

Open Hoods and Connecting Ductwork*							Tanks			
Type A		Type B		Type C		Application and Corrodent	Type A		Type B	
Cold	180 F	Cold	180 F	Cold	180 F		Cold	180 F	Cold	180 F
E	E	E	G	E	F	Anodized Oxide Coatings from Aluminum 2% CrO <sub>3</sub> , 10% H <sub>3</sub> PO <sub>4</sub> , 0.6% Wetting Agent.....	E	G	E	F
E	G	E	G	E	P	Brass from Steel 7% (NH <sub>4</sub> ) <sub>2</sub> S <sub>2</sub> O <sub>8</sub> , 30.1% NH <sub>3</sub> .....	G	P	G	P
E	E	E	E	E	F	Chromium from Brass, Copper or Nickel 11% HCl.....	E	G	E	F
E	E	E	G	E	F	Copper from Non-ferrous Metals 21% Na <sub>2</sub> S, 1.5% S.....	E	G	E	F
E	E	E	E	E	F	Lead from Copper Alloys and Steel 1% H <sub>2</sub> SO <sub>4</sub> , 20% CH <sub>3</sub> COOH.....	E	G	G	P
G	F	F	P	F	P	Lead and Alloys from Silver 1.5% H <sub>2</sub> O <sub>2</sub> , 95% CH <sub>3</sub> COOH.....	P	NR	P	NR
E	E	E	E	E	F	Tin from Brass, Bronze or Copper 10.5% FeCl <sub>3</sub> , 15.7% CuSO <sub>4</sub> · 5H <sub>2</sub> O, 26.3% CH <sub>3</sub> COOH.....	E	G	E	F

\* Ratings for closed hoods and connecting ductwork fall between ratings for tanks and ratings for open hoods and connecting ductwork.

Any discussion of this article not published above  
will appear in the June, 1960 issue.



## DISCUSSIONS

**Observations on the Mechanisms and Kinetics of Aqueous Aluminum Corrosion. Part 1—Role of the Corrosion Product Film in Uniform Aqueous Corrosion of Aluminum by V. H. Troutner. Part 2—Kinetics of Aqueous Aluminum Corrosion by R. L. Dillon. Corrosion, Vol. 15, No. 1, 9t-12t (1959) Jan.**

**Comments by P. M. Aziz and Hugh P. Godard, Aluminium Laboratories, Ltd., Kingston, Ont., Canada:**

Troutner has reported: "If the corrosion (of aluminum by high purity water) is determined by the solubility of the oxide film, the presence of dissolved aluminum ions could inhibit corrosion by a common ion effect. This effect has been observed."

In the second part by Dillon, the author stated: "It has been observed experimentally in dynamic test facilities at Hanford that, as deionized water is equilibrated with aluminum oxide at test temperature, it becomes less corrosive."

In independent work underway when these papers appeared, we had found a similar effect in distilled water at 60°C. When superpurity aluminum (99.99 Al) was immersed for a fixed time of 20 minutes in distilled water containing different amounts of aluminum ions (introduced by pre-exposing the water to aluminum coupons for varying time periods), the degree of oxidation (as measured by the weight increment) increased with the exposure time and approached a limiting value. Test coupons were 5 by 10 cm, and their surfaces were abraded with a wire brush before use. All weighings were made on an analytical microbalance; the water volume used was 600 ml. A representative series of results is given in Table 1.

These data are interpreted by assuming that in aluminum-unsaturated water there is first weight loss and then film growth so that the weight gain figures in Table 1 are the resultant of the two processes whereas in fully saturated water only film growth occurs.

**TABLE 1—Influence of Aluminum Ions on Oxidation in Distilled Water at 60°C**

Pre-exposure Time (min)	20-minute Weight Gain (micrograms/Dm <sup>2</sup> )
15	185
30	225
60	256
90	1450
120	1925
240	4834
450	7272
660	7500
1000	8290
1800	8255

It has been shown by using radiographic techniques<sup>1</sup> that, when aluminum is immersed in water, there is intense local action over the entire surface. Local cells soon passivate, probably by the precipitation of a film of aluminum hydroxide. Such a film will only precipitate when its solubility product is reached and the presence of aluminum ion in the water (solubility is very low) will speed up this precipitation (i.e. passivation).

We believe that this new observation may have considerable practical significance. It is generally accepted<sup>2,3</sup> that the pitting of aluminum is autocatalytic. We believe further that once a pit survives the initiation stage it will continue to propagate independently of the reason for its origin.<sup>3</sup> It follows that any means of stifling initiation may prevent pitting that would otherwise develop during the early life of an aluminum surface in water. When the water is saturated with aluminum ions, the introduction of more such ions by local action will bring about immediate precipitation of protective aluminum hydroxide. In the absence of sufficient aluminum ions, local action will continue until saturation is reached, and by this time some pits may have established themselves. Pre-saturation of the first aqueous charge in an aluminum tank or pipeline might lead to prompt passivation without pitting that might otherwise occur and surface film thickening which would have greater resistance to pitting in the normal environment.

While we believe that the findings of Troutner and Dillon and our own data constitute the first published evidence to support the conclusion that corrosion of aluminum in water is influenced by the aluminum content of the water, it is interesting to note that such a mechanism was proposed as far back as 1911.<sup>4,5</sup>

### References

1. P. M. Aziz. Radioactive Tracers in the Study of Pitting Corrosion on Aluminium. *J. Electrochem Soc.*, 101, 120-123 (1954) March.
2. E. Edeleanu and U. R. Evans. Causes of the Localized Character of Corrosion on Aluminium. *Trans Faraday Soc.*, 346, 47 (1951) Oct.
3. P. M. Aziz and H. P. Godard. Influence of Specimen Area on the Pitting Probability of Aluminium. *J. Electrochem Soc.*, 102, 577-79 (1955) Oct.
4. Heyn and Bauer. *Mitteilungen aus dem Koniglichen, Material prufungsamt*, 29, 16 (1911).
5. R. Seligman and P. Williams. *J. Inst Met* (London), 23, 159-192 (1920).

### Reply by R. L. Dillon:

It may be appropriate to mention that a document from the General Electric Company, Hanford Laboratories Operation, "Dissolution of Aluminum Oxide as a Regulating Factor in Aqueous Aluminum Corrosion," by R. L. Dillon, (HW-61089) will be issued shortly.

**Oil Refinery Applications of Thick-Film Synthetic Coatings by R. W. Maier, W. B. Cook and R. B. MacQueen. Corrosion, Vol. 15, No. 4, 171t-178t (1959) April.**

**Question by Charles M. Stanbury, Horton Steel Works, Fort Erie, Ontario, Canada:**

In your hot spray vinyl system you use a cold vinyl primer. Have you anything against the use of a hot vinyl primer?

### Reply by R. W. Maier:

As a general policy, we followed the manufacturer's recommendations in these applications. The primer recommended under these hot spray vinyls was a cold applied material which was not a vinyl but was described as a drying oil modified zinc chromate primer. This would tend to be a better wetting primer than a vinyl. Note Austin K. Long's comment below.

**Questions by Emile E. Habib, Dewey & Almy Chemical Co., Cambridge, Massachusetts:**

1. Are the catalyzed epoxy modified phenolics 100 percent reactive or must they contain solvents?

2. What are the hot spray vinyls? You mentioned solvents. Are they organosols, plastisols or some other composition?

### Reply by R. W. Maier:

1. The catalyzed epoxy-modified phenolics we tried all contained solvents. Whether or not anyone makes a 100 percent solids material, I do not know.

2. The hot spray vinyls described are not organosols or plastisols but solvent-type compositions, formulated with a high solids content and with high boiling solvents. As such, they have a relatively high viscosity and cannot be sprayed at room temperatures, but when heated to approximately 160°F, the viscosity is reduced to a point where the formulation can be sprayed.

**Comment by Austin K. Long, Glidden Company, Cleveland, Ohio:**

Primers for use under vinyls may be of other generic types, but primers are available which can also be hot-sprayed.

**Questions by DuWayne Christofferson, Chicago, Illinois:**

You have primarily used and discussed catalyst cured phenolic modified epoxy coatings. Why have you been using these in preference to straight catalyst cured epoxies?

Have you experience with straight catalyst cured epoxies inside (immersion service) of oil and gasoline storage tanks?

### Reply by R. W. Maier:

At the time the paper was written,

aside from the heavy consistency formulations used as tank seam sealers, we did not have any experience with the straight catalyst cured epoxies. We had hesitated to make any interior vessel applications due to their generally acknowledged chalking qualities. However, since the paper was written and a few months before its presentation, Port Arthur made a spray application after sandblasting of a red inhibitive catalyst cured straight epoxy primer and the same type finish (about 3 mils each coat) in a coral color to the exterior of two cone roofed 50-foot diameter by 30-foot high tanks used for treating 200 F waste oil emulsion with caustic. Slight pinholing of the primer was observed after application, and the finish coat began to chalk rather rapidly and presented a faded appearance after two months' exposure. But again, this is our only experience with this type coating.

**Impedance Characteristics of Isolated Aluminum Oxide Films by D. F. MacLennan. Corrosion, Vol. 15, No. 6, 283t-285t (1959) June.**

**Comments by F. E. DeBoer, Argonne National Laboratory, Lemont, Illinois:** Mr. MacLennan's attack on this problem is interesting, and his method for forming a framed oxide is clever.

It is interesting to note that his resistances are of the same order as those found by Burwell and May<sup>1</sup> for completely anodized film. They also indicate that the HgCl<sub>2</sub> process for dissolving aluminum does affect the oxide layer in such a way as to cause higher resistance of the film. We anodized both 1100 (2S) aluminum and a high purity (99.999 percent) aluminum in a manner similar to MacLennan's and then separated the oxide from the metal by HgCl<sub>2</sub>. Our measurements, although somewhat inaccurate, show that these films have resistances of about 10<sup>7</sup> ohms per cm<sup>2</sup> of film area. Also, the results for our two aluminum stocks were practically identical.

Thus, it seems likely that both of these metal stripping procedures change the oxide next to the metal. In the case of stripping with HgCl<sub>2</sub> solution, the product of the reaction of aluminum with the solution is insoluble and thus transforms the anodic film to a high resistance film. On the other hand, the completely anodized film is porous, and the methanol-iodine film is also of low resistance because of the solubility of the product of the reaction of aluminum with the methanol-iodine solution.

**Reference**

1. R. L. Burwell and T. P. May, Pittsburgh International Conference on Surface Reactions, Corrosion Publishing Co., Pittsburgh, Pa., 1948.

**Reply by D. F. MacLennan:**

It is not clear from Mr. DeBoer's comments what method of film resistance measurement he used. This is a point of interest if the resistances are to be compared.

It is to be expected that the insoluble reaction product, in the HgCl<sub>2</sub> stripping

procedure, would cause higher film resistances because this product adheres to the film. However, the solubility of the reaction product in the iodine-methanol procedure should result in clean, unchanged oxide films.

**Behavior of AZ 63 Alloy and Magnesium—1 Percent Manganese Alloy Anodes in Sodium Chloride Electrolyte by J. H. Greenblatt and E. Zinck. Corrosion, Vol. 15, No. 2, 76t (1959) Feb.**

**Comments by J. L. Robinson, Dow Chemical Company, Midland, Michigan.**

In Dr. Greenblatt's original paper (*J. Electrochem Soc.*, 103, 539 (1956)), he proposed  $Mg \rightarrow Mg^{++} + 2e$  as the principal anodic reaction for magnesium. The major argument for this reaction appeared to be that he found "that the quantities soluble Mg, insoluble Mg, Mg calculated from the current passed were in approximate one-to-one relationship with each other and all of these quantities are roughly half of the total weight loss."

Due to the nature of the cathode (silver-silver chloride) used in the experiments, the amount of magnesium in solution should be equal to that predicted by Faraday's law and divalent magnesium ion formation just as Dr. Greenblatt found. This must be true because the cathode reduction product is chloride ions, and thus soluble MgCl<sub>2</sub> will form to conform with the principle of conservation of charge. At the current densities used by Dr. Greenblatt, the expected anode efficiency would be in the range of 50 to 60 percent based on divalent ion formation. As the wasteful reactions for divalent magnesium ion formation would produce insoluble Mg(OH)<sub>2</sub>, it would be expected that this quantity of magnesium would also be roughly equal to the "calculated Mg" as Dr. Greenblatt found. Thus, such relationships cannot be interpreted as favoring the reaction  $Mg \rightarrow Mg^{+} + e$  as opposed to the commonly accepted reaction  $Mg \rightarrow Mg^{++} + 2e$ .

**Reply by J. H. Greenblatt:**

We agree with Dr. Robinson's comments that the soluble magnesium should equal the calculated quantity for the reasons he has pointed out. Our contention in the original paper was the fact that the similar equality of the insoluble magnesium could not be explained by *a priori* assumptions if the anodic evolution of hydrogen was ascribed to self corrosion.

Self corrosion and the difference effect explain the production of hydrogen and insoluble magnesium and the dependence of the rate of formation of these products on current density. However, they can only explain the equality of rates in the two processes (self corrosion and current carrying reaction) as fortuitous. Postulating the existence of univalent magnesium does give an *a priori* reason for the equality, but it is realized that this is not proof of the existence of univalent magnesium.

**Performance of Organic Coatings in Tropical Environments by A. L. Alexander, B. W. Forgeson and C. R. Southwell. Corrosion, Vol. 15, No. 6, 291t-294t (1959) June.**

**Comments by Seymour J. Fiebach, Carbolite Company, St. Louis, Missouri:** On page 293t, near the bottom of the page, the following statement is made: "Synthetic rubbers and vinyls are conspicuously absent among the survivors listed in the marine atmosphere. However, these types might be expected to yield more rapidly to the intense solar radiation of the tropics."

Additional clarification will be appreciated. It has been my impression that vinyls and vinyl-alkyds stand up very well under these conditions.

**Reply by A. L. Alexander:**

Perhaps we were a bit unwise in our choice of the word "conspicuously" in describing the absence of synthetic rubbers and vinyls in the survivors of the coating types exposed to the tropical atmosphere. We would like to invite Mr. Fiebach's attention to the fact that our data described only those coatings which were still performing quite satisfactorily after a minimum of six years and in the ease of the atmospheric exposure seven years of satisfactory service. These were not short term tests and constituted a most severe test for any coating.

Some of the vinyls were quite satisfactory for shorter periods, but from the large number of coatings studied only those which were most outstanding were reported in our paper. Our conclusions are based on data as presented, and certainly these data indicate that in atmospheric exposure the vinyls studied do not compare in durability with those materials reported in Tables 5 and 6.

**Corrosion Resistance of Titanium and Zirconium in Chemical Plant Exposures by P. J. Gegner and W. L. Wilson. Corrosion, Vol. 15, No. 7, 341t-350t (1959) July.**

**Question by E. G. Brink, American Viscose Corp., Marcus Hook, Pennsylvania:**

Do you feel that the type of specimen used in your pipe line corrosion tests gives a true picture of the corrosion pattern at the pipe wall since velocity effects and deposits can influence this pattern?

**Reply by P. J. Gegner:**

We recognize the limitations involved in obtaining corrosion data by means of specimens. Believing the specimen data to be indicative only, we started equipment tests almost immediately. So far, these equipment tests have confirmed the results obtained by means of the specimens.

**Comments by Wayne H. Keller, National Research Corp., Waban, Massachusetts:**

This report has great value to industry in the unusual extent of its coverage. In



general, the findings agree very well with those reported elsewhere.

Since some of the earlier reports on corrosion resistance of zirconium were based on induction melted metal higher in carbon than the present product, it would be helpful to know the melting and fabrication history of the zirconium samples. Since the carbon is low, it is assumed that the product used is arc melted. Melting atmosphere would be of interest. (It was established by the writer that the sponge used was double melted by arc in vacuum by the consumable electrode process.) Also, the rolling and heat-treating histories will affect the corrosion behavior and would be of interest.

The behavior of the stainless steels tested in the concentration of the raffinate from solvent extractions, reported as nitric acid solutions is not necessarily surprising. Assuming that the solutions described as "typical of those found in the separation and concentration of nitric acid from . . . raffinates" was actual zirconium plant raffinate, it may contain sulfate ion up to 2 to 3 percent of the concentration of the nitric acid along with a saturation amount of sodium nitrate and varying quantities of many other nitrates, including ferric. The effect of such varied and varying composition may be expected to be rather different from that of nitric acid. Moreover, the quoted values of chlorides required to increase the attack by nitric acid on stainless steel was not the quantity required to initiate attack but was tolerated only by rather extensive preventive maintenance and replacement programs.<sup>1</sup>

The fact that zirconium stood up well comparably with tantalum under raffinate concentration service is one of its best recommendations. Continued reports of the results of these studies will be watched with great interest.

#### Reference

1. D. S. Arnold, A. Whitman and F. J. Podlipiec. Nitric Acid Recovery from Raffinate. *Chem. Engineering Progress*, 52, No. 9, 362 (1956) Sept.

#### Comments by Milton Stern and Claude R. Bishop, Union Carbide Metals Company, Niagara Falls, New York:

The authors are to be commended for providing the corrosion field with an unusually valuable report. It is quite evident that this test program provides particularly valuable data and that it has been competently planned and executed. Corrosion workers will be indebted for many years to the authors and Columbia-Southern Chemical Corporation for their foresight in embarking on this program and in making the information so generally available.

We have been working on the corrosion and electrochemical behavior of titanium on a laboratory scale for several years and have been particularly impressed by the ease with which the metal is passivated and the stability of the passive state in the presence of chlorides and chlorine. In fact, chlorine seems to behave like any other oxidizing agent in actually promoting passivity of titanium. Our laboratory tests on the resistance of titanium to solutions of

sulfuric acid with chlorine are confirmed by these plant tests. Tests conducted at 190 C show that chlorine is an effective passivator in hydrochloric acid as well as in sulfuric acid and indicate that the authors' current experiments on the influence of chlorine in hydrochloric acid environments will again show titanium to be an outstanding material of construction.

As brought out by the authors, titanium shows excellent corrosion resistance to a wide variety of media which, in general, can be classified as oxidizing in nature. It is well known that titanium is not particularly resistant to so called reducing acids, such as hydrochloric or sulfuric acids without the presence of oxidizing agents. In an investigation to overcome this defect, addition of relatively small percentages of a noble metal markedly improved the corrosion resistance to reducing environments.

For example, titanium containing palladium exhibits corrosion rates of 32 mpy in boiling 10 percent hydrochloric acid and 20 mpy in boiling 5 percent sulfuric acid. Rates for unalloyed titanium are well over 1000 mils per year in either solution. This is achieved without detrimental effects to titanium's excellent behavior in oxidizing media and results in a material with unusually broad resistance to a variety of different environments.

Although not advocated for service in the more aggressive solutions of sulfuric and hydrochloric acids, the palladium-bearing alloy has all indications of greatly extending the usefulness of titanium into environments in which it cannot now be used. It should be particularly valuable in those plants which periodically alternate between reducing and oxidizing conditions.

#### Reply by P. J. Gegner:

We are pleased to learn that some of our tests confirm laboratory results obtained by Doctors Stern and Bishop, particularly in regard to the influence of chlorine on rendering titanium passive in strong sulfuric and hydrochloric acid solutions.

We are very much interested in their comments on the effects of small additions of noble metals on the corrosion resistance of titanium to reducing environments. This promises to be another important milestone in the history of titanium. We are happy to offer the facilities of our company in evaluating these new alloys under plant operating conditions.

#### Corrosion of Types 316 and 317 Stainless Steel by 75 Percent and 85 Percent Phosphoric Acid by Albert R. Morgan, Jr. Corrosion, Vol. 15, No. 7, 351t-354t (1959) July.

#### Questions by C. M. Schillmoller, International Nickel Company, Inc., Los Angeles, California:

Have you an explanation why the Carpenter 20 and the Hastelloys did not show better resistance to hot phosphoric acid than Type 316 and 317 stainless

steel? Also, was Nionel evaluated and what were your findings?

#### Reply by A. R. Morgan:

We have no explanation why Carpenter 20 and the Hastelloys were not more resistant than 316 and 317 stainless steel. It is our impression that the Alloy 803 mentioned in Table 8 is now called Ni-O-Nel.

#### Cathodic Protection of Lead Cable Sheath by W. H. Bruckner and Ole G. Jansson. Corrosion, Vol. 15, No. 7, 389t-394t (1959) July.

#### Question by R. B. Mears, U. S. Steel Research Center, Monroeville, Pennsylvania:

What proof is there all the corrosion occurred in Cell B during the periods when the current was off?

#### Reply by W. H. Bruckner:

It appears that in preparing the article we omitted one observation regarding the appearance of the corroded portion of the gradient cathode Series B at the high pH end. We noted that the corrosion products near the air-soil interface had a yellow-red color, but near the bottom where perforation occurred there was also a considerable amount of re-deposited lead. We have considered that the re-deposited lead together with the experience of the cell of Series A operated at 14 pH justifies the conclusion we made. It is seen from the gradient cells that a sufficiently negative potential can give complete protection even at a pH of 14. The potential at the high pH end was not determined; however, it is indicated that since lead was deposited it was sufficient to provide complete protection while the cell received current. Thus the only opportunity for corrosion loss was during periods of open circuit.

#### Comments by L. C. Eddy, Hinsdale, Illinois:

The authors should be commended for their imaginative study and original approach to this complicated subject which has so many ramifications. This article is a fitting follow-up of two previous articles directly associated with this same general study.

The authors developed the "Gradient Cell" into a very useful tool. The cell gave the opportunity to observe the effect of a relatively wide variation of cathode current densities on adjacent areas while the other elements were well controlled. The "Gradient Cell" principle should be a very valuable tool in other investigations involving electrolytes and current densities. The cell in itself does not permit the direct evaluation of specific current densities, but that step if desired should not be difficult.

The authors' findings may be difficult for some of us to comprehend and to apply. In particular for us who have based our thinking on a limited metal plating experience or on field observations of corrosion results where the action is in a duct system and where the various forces and factors cannot be ade-

quately observed or measured. Under the authors' definition, cathodic corrosion is not possible except at very high current densities (30,000 to 120,000 MA per square foot) which should be beyond the densities encountered in cable sheath corrosion. It is of academic interest to learn that the current required for such action increases so fast with the increased pH of the electrolyte. It was fortunate that recent findings from a lead study by Pourbaix were published and could be used.

The corrosion engineer can be encouraged by the laboratory findings which indicate that lead cable sheath in a high pH electrolyte can be protected from corrosion by maintaining it sufficiently cathodic. Then again he can be discouraged when he understands the number and degree of controls required to obtain that protection. The effort in simple form is to eliminate discontinuities in the environment. Or, the effort is to maintain a uniform environment for the cable sheaths which leads me to a greater consideration of jacketed cables.

#### Reply by W. H. Bruckner:

We enjoyed Mr. Eddy's commendation of our work and feel as he does that the research has done much to clarify some of the complications which may exist in service of lead sheaths. In the laboratory the variables can and must be separated in order to undertake their study. In the field, conditions may vary with respect to location and time sequence. Mr. Eddy provides the key to greater service life of lead sheath in his comment that discontinuities in the environment should be eliminated. Unfortunately where discontinuities prevail and the conditions are severe, the only solution to the problem may be the use of jacketed cables, as mentioned by Mr. Eddy.

He mentions the use of the gradient test cell for other investigations. We have heard of a number of applications of this method by other laboratories for corrosion behavior studies of different metal and environmental systems. We have used it in the Cathodic Protection Laboratory for studies on steel and aluminum under cathodic protection. Where current densities need to be known for the gradient test, a sectional cathode or a probe in the electrolyte would be required to determine these values.

#### Comments by Vernon B. Pike, Murray Hill, New Jersey:

The authors are to be commended in accomplishing the results of the study reported in this and two previous papers. They have made clear several factors which have been repeatedly observed in the cases of cathodic corrosion we have studied. Actually no cases of cathodic corrosion of lead cable sheath have been brought to my attention in the last several years. Examining the cases of such corrosion recorded in my files, I find that there were high current densities and build-up of substances at the lead surfaces by the cathodic currents. These products were believed to influence the attack on the lead at such times as the currents decreased.

Studies made at the Bell Telephone Laboratories on soils gathered from 47 widely separated places in the United States gave a band of voltages at which lead was at neutrality when plotted against the soil pH. This band was about 64 millivolts in width.

#### Reply by W. H. Bruckner:

We assume the experience that Mr. Pike cites regarding the decreased incidence of alkaline corrosion under cathodic protection conditions concerns the Eastern Atlantic area. This would indicate improved control of conditions of cathodic protection on lead cable sheath. It is suggested from Mr. Pike's comments that this control has been achieved by decrease in the alkaline product of cathodic protection. This product would be a minimum under conditions of minimum continuous protective current and maximum uniformity of cable environment.

#### Comments by Frank E. Kulman, Consolidated Edison Company of New York, Inc., New York City:

The authors have shown that severe corrosion of lead in an alkaline environment can be caused by fluctuations in current flowing from the electrolyte to the lead cathode.

Whether this corrosion is called cathodic corrosion or corrosion by cathodic products is not particularly important to the corrosion engineer. The corrosion engineer has maintained for many years that stray currents leaking from d-c railways have caused corrosion of lead sheath in areas where the potential of the lead was negative with respect to the earth and to the rail and a low resistivity electrolyte was present. The authors perhaps unwittingly corroborate what the cable corrosion engineer has intuitively known for years.

Interestingly enough, the corroboration of the idea resulted in part from accidental failures of the impressed current circuit at times when the laboratory was unattended, that is, during evenings and weekends.

It is felt also that the outcome resulted from the use of soil electrolyte and non-uniform current density on the lead cathode. The soil acted as a partial barrier to keep the alkaline polarization products from diffusing away from the lead. The non-uniform current density resulted in variations of alkalinity along the lead electrode and indirectly in variations in equilibrium potential of the lead referred to the adjacent soil. Thus, at the high current density end of the buried electrode, the pH was approximately 14 and the equilibrium potential of the lead approximately -0.6 volts. At the low current density end of the electrode, the pH was about 9 and the equilibrium potential about -0.3 volts. Thus, when the impressed current circuit was interrupted, the lead electrode with its surrounding electrolyte formed a 0.3-volt galvanic cell, the anode being surrounded by soil at pH 14 and the cathode by soil at pH 9. This would account for the severe corrosion found at one end of the electrode.

The galvanic cell which existed in the laboratory is an over simplification of the field condition where the lead sheath is electrically connected to iron pipes. Other investigators have shown that in an alkaline environment, lead is anodic to iron. Thus, interruption of an impressed current circuit would cause the portion of lead which received a high cathodic current to become anodic not only to the other portions of lead but also to large areas of nearby iron pipe. Needless to say, the corrosive attack would be greater with the lead connected to iron.

#### Reply by W. H. Bruckner:

Mr. Kulman aptly suggests the existence of concentration cells in a pH gradient and the reversal of potential of iron-lead cell in service with sufficient (alkalinity). It is also true as he points out that prior cathodic protection at excessive levels in soil produces the environment of high alkalinity which accounts for the severe corrosion. There is however another factor which is cited and which has not previously been given field consideration and this is the clean, film free surface due to excessive cathodic protection. The clean surface has a maximum initial corrosion rate, thus short periods of corrosion on open circuit interspersed with periods of recleaning under cathodic protection could account for the rapid losses experienced in the Series B tests.

#### Comments by J. J. Pokorny, Cleveland Electric Illuminating Co., Cleveland, Ohio.

Mr. Pike has said that cathodic corrosion of cable sheaths does not occur very often and that he has not seen or heard of a case in several years.

This is surprising because in Cleveland we find that between 40 and 60 percent of our lead cable sheath corrosion occurs in stray current areas where the cable sheath is cathodic. The corrosion of the sheath found in these areas is easy to identify and is characteristic of this type corrosion. The lead is corroded away in long grooves and patches and in these corroded areas it is usually covered with yellow, orange or red lead compounds. Re-deposited buttons and tongue shaped islands of gray lead are usually found between the grooves and pitted areas.

I am sure that the communication people in our area have experience very similar to ours. It is very difficult to believe, that the conditions in Cleveland are unique. I feel that this type of corrosion must be prevalent in other localities also, but the people have come to call this type corrosion something other than cathodic corrosion.

We feel that we must classify this type corrosion as cathodic corrosion because it is the negative polarity which creates the alkaline condition causing the initial corrosive attack on the lead. In order to mitigate the corrosive condition, we must remove or reduce the negative condition of the sheath by any one of several means available in any specific case.



**Reply by W. H. Bruckner:**

Mr. Pokorny's comments indicate experience at variance with that of Mr. Pike. We have also heard at various NACE meetings of current problems with alkaline corrosion of cathodically protected lead cable sheath. It is our hope that the data we have presented will help to reduce the incidence of such corrosion.

We have seen some examples of the corrosion pattern which Mr. Pokorny describes with long grooves or patches corroded out of the lead sheath where it contacted the duct or at the air interface of the water remaining in dip sections. The examples we have seen, however, were not accompanied by colored corrosion products or redeposited lead, thus indicating causes other than the cathodic protection system. As we have cited, service failure is the integrated effect of (1) any corrosion occurring during cathodic protection due to insufficient current, (2) any corrosion occurring after cessation of cathodic protection due to low water level and (3) periodic stray current of sufficient level to cause positive polarity. We still prefer calling these corrosion due to cathodic products or alkaline corrosion because in every case active anodes exist except where adequate cathodic protection is maintained.

In summary, we would like to thank the discussers of the article for their interest and for confirming the authors' hopes of maximum effectiveness of the data in coping with service conditions of cathodically protected lead cable sheath.

**Duct Anode Development and Experience in Protection of Underground Cables From Corrosion by J. E. Johnson. Corrosion, Vol. 15, No. 8, 423t-427t (1959) Aug.**

**Comments by David T. Jones, Pacific Telephone Co., Los Angeles, California:**

We developed and installed a graphite anode in October, 1951, of a design explained in this article.

The anode was made from a standard commercial 3-inch by 60-inch graphite anode, which was cut into five 12-inch lengths, each length turned on a lathe to a 2-inch diameter. A  $\frac{1}{2}$ -inch hole was drilled through the center lengthwise for a No. 6 insulated copper wire. Each end was counter-bored for about  $3\frac{1}{2}$  inches and at a  $\frac{3}{4}$ -inch bore. Wire insulation was removed for distances of 5 inches at intervals of 3 feet. The wire

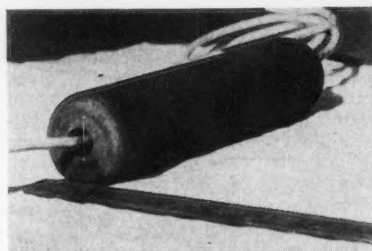


Figure 1—Twelve-inch by 2-inch diameter graphite anode made from a 3-inch by 60-inch anode. Copper wire was used to string the anodes.

was threaded through the anodes and the bare portion positioned so that the center of the bare wire and anodes coincide.

One end of the counter-bore was plugged while molten wiping solder was poured into the area between the bare copper wire and graphite anode until it filled up to the bottom of the top counter-bored area. The two counter-bored spaces were filled with a sealing compound. The completed anode resembled a sausage string. One of the anodes is shown in Figure 1.

This anode system was in operation until early 1958, when failure occurred because of compound seal failure around the anode wire, allowing moisture to contact the wire which thus became part of the anode system.

We have used junk lead-sheathed cable or a special electrolysis lead control cable for over 20 years as duct anodes with excellent and efficient results.

The anodes on the sausage string were placed at 3-foot intervals in order to be located near the joints in the multi-duct vitrified clay conduit.

**Stress Corrosion Cracking of Oil Country Tubular Goods by R. L. McGlasson and W. D. Greathouse. Corrosion, Vol. 15, No. 8, 437t-442t (1959) Aug.**

**Questions by H. Lee Craig, Jr., Reynolds Metals Co., Richmond, Virginia:**

1. What is the location, direction and extent of the crack which is produced in your notched specimen?
2. What surface preparation do you apply following the machining of the notch, including the removal of machining oils, etc.?

**Reply by R. L. McGlasson:**

1. The cracks initiated in all but two

of the several hundred specimens tested to date were at one side of the notch root rather than at its actual apex. This could be due to some minute and undetected sharp radius of curvature gradient produced by the juncture of the straight tangential edge of the milling cutter and the radius portion of the cutter. As far as we know, however, this is not the case. It seems more likely that this off-center position represents the microscale boundary region of plastic and elastic deformation. It is in this region of high atomic distortion that the maximum susceptibility to hydrogen and/or stress cracking effects would be expected. Previous investigators have demonstrated theoretically and experimentally that this region occurs at about 45 degrees to the notch axis for hyperbolic notches.<sup>1</sup>

The two anomalous failures occurred at comparatively shallow metal stamp identification marks, well away from the notched region. These results indicate the extreme importance of cold work on initiating these cracks.

The cracks proceed directly across the specimen from the point of initiation. The harder samples frequently crack completely through the cross-section. The softer ones usually have a thin region ( $\frac{1}{8}$  to  $\frac{1}{4}$  of section) on the inner surface still intact. The softer ones always show some dimple on the sample edge, indicating that after initiation at least part of the crack propagation involves normal yielding. This effect is not readily apparent on the harder samples. Thorough metallographic study of these specimens has not been made; consequently, we have no data on the relation of the crack to microstructural morphology.

2. Following the machining, the specimens were washed thoroughly in naphtha, then in acetone. Several washes of each were used. No other cleaning was done. The notch surface is left in the as-machined condition.

**Reference**

1. Hendrickson, Wood and Clark. Brittle Fractures in Mild Steel. *ASM Trans*, 50, 656-675 (1958).

**Comments by Joe Chittum, Whittier, California:**

We have tried to solve the problem of determining the stress that is applied to a specimen by putting the bar totally under tension.

The place where the stress corrosion cracking was produced was limited by limiting contact length between corrosive solution and bar.

Discussions of technical articles appear in the June and December issues only when they do not immediately follow the article to which they pertain. Discussions received from November through April will appear in the June issue and those from May through October in the December issue.



# ERRATA—CORROSION, Volumes 14 and 15

**Comparison of Corrosion Engineering or Materials Engineering Functions in Various Chemical Plants** by L. W. Gleekman. Corrosion, Vol. 14, 540t (1958) Nov.

Entry under heading "Investigates Paint Problems" for General Chemical Div., Allied Chemical & Dye, Camden, New Jersey, should read:

X  
instead of No

The letter "X" will indicate that this company *does* investigate paint problems.

**Zinc in Marine Environments** by E. A. Anderson. Corrosion, Vol. 15, No. 8, 409t-412t (1959) August.

On page 411t, Tables 10 and 11 at bottom of this errata page should be substituted for Tables 10 and 11.

On page 411t, column 1, second line from the bottom should be changed to read:

vanized sheets were perforated after 26

**Design and Materials for Reduced Pump Corrosion** by Jack E. Piccardo. Corrosion, Vol. 15, No. 9, 473t-476t (1959) September.

Page 476t, middle column, first two lines of J. E. Piccardo's reply to A. V. Morrison should read as follows:

1. Cavitation erosion is a dynamic action within the fluid and cannot be over-

**Effects of Foreign Metals on Corrosion of Titanium in Boiling 2M Hydrochloric Acid** by Roger Buck, III, Billy W. Sloope and Henry Leidheiser, Jr. Corrosion, Vol. 15, 566t-570t (1959) Nov.

On page 570t, column 3, two sets of numbered references appear. The top set, numbered one through seven with all numbers in parenthesis, apply to Table 4 of the article rather than to the text. The six references immediately below this group apply to the text.

**Abstract Section.** Pages of the Corrosion Abstracts section in the January and February 1959 issues were numbered incorrectly in the lower outside margins where the "a" series numbers are carried. The January issue should have begun with 1a and ended with 18a. The February issue should have begun with 19a and ended with 28a. Corrected numbers are reproduced below for pasteup correction of these two issues:

1a	2a	3a	4a	5a	6a	7a
8a	9a	10a	11a	12a	13a	14a
15a	16a	17a	18a	19a	20a	21a
22a	23a	24a	25a	26a	27a	28a

TABLE 11—Calculated and Observed Coating Life

Location	Weight of Coating (a)	Time to 100% Rust—Years		Time to Perforation of Black Iron—Years
		Observed	Calculated	
Key West.....	2.5	> 26	99	..
Key West.....	2.0	> 26	79	..
Key West.....	1.5	> 26	60	..
Key West.....	1.25	> 26	50	..
Key West.....	0.75	> 26	30	..
Key West.....	None	....	..	3.9
Sandy Hook.....	2.5	> 25	30	..
Sandy Hook.....	2.0	> 25	24	..
Sandy Hook.....	1.5	17.9	18	..
Sandy Hook.....	1.25	15.2	15	..
Sandy Hook.....	0.75	11.3	9	..
Sandy Hook.....	None	....	..	7.3 (b)
State College.....	2.5	> 32	50	..
State College.....	2.0	> 32	40	..
State College.....	1.5	> 32	30	..
State College.....	1.25	> 32	25	..
State College.....	0.75	23.5	15	..
State College.....	None	....	..	26

(a) In ounces per square foot of sheet.

(b) Average of sheets showing failure—final average may be higher.

TABLE 10—Atmospheric Corrosion of Corrugated Galvanized Sheets

Location	Steel Gauge	Weight of Coating (a)	Time in Years To—				
			First Rust	100% Rust	Sheet Perforation	Rust (b) Spots	Perforation from Below (b)
Key West.....	22	None	.....	.....	3.9	.....	.....
Key West.....	16	2.5	> 26	> 26	> 26	> 26	21.9—> 26
Key West.....	22	2.5	> 26	> 26	> 26	25.5	24.3—> 26
Key West.....	22	2.0	> 26	> 26	> 26	22.8	25.5
Key West.....	22	1.5	> 26	> 26	> 26	19.8	21.5
Key West.....	22	1.25	21.5—> 26(c)	> 26	> 26	19.8	22.8
Key West.....	22	0.75	18.3(d)	> 26	> 26	12.5(d)	17.5(d)
Key West.....	28	0.75	18.7(d)	> 26	> 26	13.1(d)	18.9(d)
Sandy Hook.....	22	None	.....	.....	7.3(d)	(e)	(e)
Sandy Hook.....	16	2.5	11.8	> 25	> 25	(e)	(e)
Sandy Hook.....	22	2.5	13.1	> 25	> 25	(e)	(e)
Sandy Hook.....	22	2.0	9.9	> 25	> 25	(e)	(e)
Sandy Hook.....	22	1.5	7.6	17.9	> 25	(e)	(e)
Sandy Hook.....	22	1.25	6.8	15.2	> 25	(e)	(e)
Sandy Hook.....	22	0.75	4.8	11.3	> 25	(e)	(e)
Sandy Hook.....	28	0.75	4.9	11.1	> 25	.....	.....
State College.....	22	None	.....	.....	26	(e)	(e)
State College.....	16	2.5	24.6	> 32	> 32	(e)	(e)
State College.....	22	2.5	26.3(d)	> 32	> 32	(e)	(e)
State College.....	22	2.0	22.5	> 32	> 32	(e)	(e)
State College.....	22	1.5	17.1	> 32	> 32	(e)	(e)
State College.....	22	1.25	14.6	> 32	> 32	(e)	(e)
State College.....	22	0.75	10.0	23.5	> 32	(e)	(e)
State College.....	28	0.75	11.1	24.0	> 32	(e)	(e)

(a) In ounces per square foot of sheet coated both side.

(b) Rust spots and perforation due to corrosion from below penetration zinc coating on upper side.

(c) Only one sheet showed first rusting—remaining 16 showed no rust in 32 years.

(d) Average of sheets showing failure—final average may be higher.

(e) Corrosion from below did not occur at this site.

# REPRINTS

## Of Articles Published In Corrosion

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- The Performance of Alcan 655-T6 Aluminum Alloy Embedded in Certain Woods Under Marine Conditions by T. E. Wright, H. P. Godard and I. H. Jenks.....50
- Application of Statistical Theory of Extreme Values to the Analysis of Maximum Pit Depth Data for Aluminum by R. M. Aziz.....50
- Mechanism of Inhibiting Effect of Hydrofluoric Acid in Fuming Nitric Acid on Liquid-Phase Corrosion of Aluminum and Steel Alloys by Davis M. Mason and John B. Rittenhouse.....50
- An Eddy Current Gauge for Measuring Aluminum Corrosion by W. E. Ruther.....50
- The Corrosion Behavior of Aluminum by Hugh P. Godard.....50
- Aqueous Corrosion of Aluminum—Part 2—Methods of Protection Above 200 C by J. E. Draley and W. E. Ruther.....50
- Compatibility of Aluminum With Alkaline Building Products by C. J. Walton, F. L. McGeary and E. T. Englehart.....50
- Structural Features of Corrosion of Aluminum Alloys in Water at 300 C by Kurt M. Carlsen.....50
- The Static Electrode Potential Behavior of Aluminum and the Anodic Behavior of the Pure Metal and Its Alloys in Chloride Media by E. M. Khairy and M. Kamal Hussein.....50
- Reaction of Certain Chlorinated Hydrocarbons with Aluminum by A. C. Hampstead, G. B. Elder and J. C. Canterbury.....50
- Effects of Cold Working on Corrosion of High Purity Aluminum in Water at High Temperatures by M. J. Lavigne.....50

### Cathodic Protection and Pipe Lines

- Cathodic Protection of Internals of Ships by L. P. Sudrabn.....50
- Cathodic Protection of Oil Well Casings at Kettleman Hills, California by J. K. Ballou and F. W. Schremp.....50
- Cathodic Protection of an Active Ship Using Zinc Anodes by B. H. Tytell and H. S. Preiser.....50
- Polarization in the Corrosion of Ice Breakers by J. H. Greenblatt.....50
- The Application of Cable in Cathodic Protection—Part I by M. A. Riordan and Part II by R. G. Fisher.....50
- Economic Considerations in Pipe Line Corrosion Control by L. G. Sharpe.....50
- Application of Cathodic Protection to 48 Well Casings and Associated Production Facilities at Waskom Field by G. L. Doremus, W. W. Mach and J. J. Lawnick.....50
- Potential Criteria for the Cathodic Protection of Lead Cable Sheath by K. G. Compton.....50
- Current Requirement for Cathodic Protection of Oil Well Casing by E. W. Haycock.....50
- Electrochemical Deterioration of Graphite and High-Silicon Iron Anodes in Sodium Chloride Electrolytes by S. Tudor, W. L. Miller, A. Ticker and H. S. Preiser.....50
- The Use of Magnesium for the External Cathodic Protection of Marine Vessels by C. F. Schriber.....50
- Cathodic Protection of Lead Cable Sheath in the Presence of Alkali from Deicing Salts by Walter H. Bruckner and W. W. Lichtenberger.....50
- Microbiological Deterioration of Buried Pipe and Cable Coatings by F. E. Kulman.....50

- Electrical Measurements and Their Interpretation in Underground Cable Corrosion Problems by K. G. Compton.....50

### Coatings

- How to Determine a 'Comparable Cost' for Paints by V. B. Volkening and J. T. Wilson, Jr.....50
- Testing of Cool Tar Coatings (II)—Field Exposure in Cold Climates by W. F. Fair, Jr., C. U. Pittman and M. G. Sturrock.....50

### Inhibitors

- Evaluation of Refinery Corrosion Inhibitors by A. J. Freedman and A. Dravnieks Developments in Cooling Tower System Treatments (Part 1—Polyvalent Ion-Polyphosphate Inhibitors) by J. I. Bregman and T. R. Newman.....50
- Corrosion Inhibitor Testing Inside a Products Pipe Line by Robert H. Meyer Dicyclohexylammonium Nitrite, a Volatile Corrosion Inhibitor for Corrosion Preventive Packaging by A. Wachter, T. Skei and N. Stillman.....50
- Inhibiting a Cooling Water Tower System by F. L. Whitney, Jr.....50
- Some Experiences with Sodium Silicate as a Corrosion Inhibitor in Industrial Cooling Waters by J. W. Wood, J. S. Beecher and P. S. Laurence.....50
- Non-Chemical Factors Affecting Inhibitor Selection and Performance in Air Conditioning Cooling Waters by Sidney Sussman.....50
- Inhibiting Effect of Hydrofluoric Acid in Fuming Nitric Acid by David M. Mason, Lois L. Taylor and John B. Rittenhouse.....50
- Nitrite Inhibition of Corrosion: Some Practical Cases by T. P. Hoar.....50
- Study of the Compatibility of Floating-Type Inhibitors and Cathodic Protection by E. R. Streed.....50

### Miscellaneous

- The Corrosion of Steel in a Reinforced Concrete Bridge by R. F. Stratfull.....50
- Some Aspects of the Corrosion Processes of Iron, Copper and Aluminum in Ethylene Glycol Coolant Fluids by P. F. Thompson (Deceased) and K. F. Lorking.....50
- Corrosion Control by Magic—It's Wonderful by H. H. Uhlig.....50
- Why Metals Corrode by H. H. Uhlig.....50
- The Relation of Thin Films to Corrosion by Thor N. Rhodin.....50
- Fundamentals of Liquid Metal Corrosion by W. D. Manly.....50
- The Oxidation of Molybdenum by E. S. Jones, Capt. J. F. Mosher, Rudolph Speiser and J. W. Spretnak.....50
- Corrosion and Metal Transport in Fused Sodium Hydroxide (Part 2—Corrosion of Nickel-Molybdenum-Iron Alloys) by G. Pedro Smith and Eugene E. Hoffman.....50
- Corrosion and Metal Transport in Fused Sodium Hydroxide—Part 3—Formation of Composite Scales on Inconel by G. Pedro Smith, Mark E. Steidlitz and Eugene E. Hoffman.....50
- Some Concepts of Experimental Design by J. D. Hromi.....50
- The Growth of Ferrous Sulfide on Iron, by R. A. Jeussner and C. E. Birchenall.....50
- Standardization in the Field on Corrosion and Corrosion-Protection in Germany by Henry Hives.....50
- A Kinetic Study of Acid Corrosion of Cadmium by Henry Weaver, Jr. and Cecil C. Lynch.....50
- Cavity Formation in Iron Oxide by D. W. Juenker, R. A. Meussner and C. E. Birchenall.....50
- Relation of Corrosion to Business Costs by Aaron Wachter.....50

- The Corrosion of Iron in High-Temperature Water. Part I—Corrosion Rate Measurements by D. L. Douglas and F. C. Zyzes.....50
- Corrosion Studies in High Temperature Water by a Hydrogen Effusion Method by M. C. Bloom, Krulfield, W. A. Fraser and Vianes.....50
- Corrosion of Metals in Tropical Environments, Part 1—Five Non-Ferrous Metals and a Structural Steel, by B. W. Forgeson, C. R. Southwell, A. L. Alexander, H. W. Mundt and L. J. Thompson.....50
- Prevention of Localized Corrosion in Sulfuric Acid Handling Equipment by G. A. Nelson.....50
- High Temperature Oxidation of Iron-Nickel Alloys by M. J. Brabers and C. E. Birchenall.....50
- Controlling Corrosion in Coal-Chemical Plants by C. P. Larrabee and W. L. Mathay.....50
- Corrosion and the Destination of Corrosion Products in a High Pressure Power Plant by Ross C. Tucker.....50
- Methods for Increasing the Corrosion Resistance of Metal Alloys by N. D. Tomashov.....50
- Corrosion of Zinc by Differential Aeration by G. Bianchi.....50

### SYMPOSIUM ON CORROSION BY HIGH PURITY WATER

- Introduction, John F. Eckel.....50
- Corrosion of Structural Materials, A. H. Roebuck, C. R. Breden and S. Greenburg.....50
- Corrosion Engineering Problems, D. J. DePaul.....50
- Importance of Data to Industrial Application, W. Z. Friend. Per Copy.....\$1.50

### Petroleum Production and Storage

- Naphthenic Acid Corrosion—An Old Enemy of the Petroleum Industry by W. A. Derungs.....50
- Analysis of Corrosion Pitting by Extreme Value Statistics and Its Application to Oil Well Tubing Caliper Surveys by G. C. Eldredge.....50
- Interpretation of Tubing Caliper Surveys by Victor W. Maxwell and Ben D. Park.....50
- A Laboratory Study of N-Oleoyl Sarcosine as a Rust Inhibitor in Some Petroleum Products by Robert M. Pines and John D. Spivack.....50
- Sulfide Corrosion Cracking of High Strength Bolting Materials by Donald Warren and G. W. Beckman.....50
- Corrosion in Amine Gas Treating Solutions by F. S. Lang and J. F. Mason, Jr.....50
- Corrosion Products of Mild Steel in Hydrogen Sulfide Environments by F. H. Meyer, O. L. Riggs, R. L. McGlasson and J. D. Sudbury.....50
- An Electrical Resistance Method of Corrosion Monitoring in Refinery Equipment by A. J. Freedman, E. S. Troscinski and A. Dravnieks.....50

### THREE PAPERS ON SULFIDE CORROSION

- A Note on the Value of Ammonia Treatment for Tank and Casing Annulus Corrosion by Hydrogen Sulfide by Walter F. Rogers.....50
- Use of Ammonia to Prevent Casing Corrosion by H. E. Greenwell, Rado Loncaric and Harry G. Byars.....50
- Electrochemical Studies of the Hydrogen Sulfide Corrosion Mechanism by Scott P. Ewing.....1.00

### Stainless Steel, Titanium

- Effect of Sigma Phase vs Chromium Carbides on the Intergranular Corrosion of Type 316 and 316L Stainless Steel (Part 1—A Survey of the Literature) by Donald Warren.....50
- The Effect of  $\text{NO}$ ,  $\text{HNO}_2$ , and  $\text{HNO}_3$  on Corrosion of Stainless Steel by  $\text{H}_2\text{SO}_4$  by W. P. McKinnell, Jr., L. F. Lockwood, R. Speiser, F. H. Beck and M. G. Fontana.....50
- Inhibiting Effect of Hydrofluoric Acid in Fuming Nitric Acid on Corrosion of Austenitic Chromium-Nickel Steels, by Clarence Levee, David Mason and John Rittenhouse.....50



# NACE NEWS



## Pittsburgh Bicentennial Science Award NATIONAL ASSOCIATION OF CORROSION ENGINEERS PITTSBURGH SECTION

PITTSBURGH SECTION was given this 9 by 7-inch bronze plaque for recognition of the section's participation in the Pittsburgh Bicentennial celebration. The section held an open house on March 5, 1959, at the Mellon Institute. Guest speaker for the occasion was C. J. Wessel, director of the Prevention of Deterioration Center, National Academy of Sciences. His talk was titled "The Scope of the Materials Deterioration Problem and the Approach to the Challenge." Pittsburgh Section members responsible for the open house included W. L. Mathay, R. W. Maier, G. L. Snair, John Vrable and S. H. Kalin.

## Western Region News

**Los Angeles Section** heard Howard Keller of Jones and Keller, Inc., discuss fluid films for corrosion protection at the November 18 meeting.

**San Francisco Bay Area Section** held a joint meeting November 10 with the Northern California chapters of the Society of Plastics Industry and Society of Plastics Engineers. Raymond B. Seymour, president of Alcyline Plastics and Chemical Corp., talked on "Plastics vs Corrosion."

R. C. Canapary, product manager of the petroleum industry section of Nalco Chemical Company, will give an illustrated paper on high temperature inhibitors for hydrocarbon environments at the December 8 meeting.

**Portland Section** heard Raymond B. Seymour, president of Alcyline Plastics & Chemical Corp., speak on "Plastics vs Corrosion" at the November 12 meeting.

Rodney Moorman of Bonneville Power Administration spoke on corrosion problems at electric power sub-stations and allied equipment at the October 8 meeting.

Western Region's 1960 Conference will be Oct. 6-7 at the Sheraton Palace Hotel in San Francisco, Cal.

In 1958, there were over 11 million privately and publicly owned trucks on U. S. streets and highways, representing 17 percent of the total U. S. motor vehicle registrations.

### Portland Section Plans April 27-29 Short Course

About 18 hours of instruction and demonstrations are being planned for the Portland Section Short Course on Corrosion to be held April 27-29.

Nine major topics are being considered for the short course: fundamentals of corrosion, recognition of corrosion types, instrumentation, corrosion survey, corrosion control methods, protective methods, corrosion prevention, literature sources and demonstrations.

The section on protective methods will include coatings and cathodic protection. Inhibitors will be included in the section on methods of controlling corrosion.

General chairman for the short course is R. V. Moorman. Vice chairman is O. Hudrlik.

Others appointed to committees are listed below.

**Program Committee:** Chairman Nealey Wood, Charlton Laboratories, Samuel Grub, Portco Corp., Sid Moore, S. S. Moore & Associates, Thomas Hayes, Cornell, Howland, Hayes & Merryfield, and Bruce Nichols, Pacific Telephone & Telegraph.

**Facilities Committee:** Chairman George Merz, Portland General Electric, J. L. Williams, Fabri-Valve Co., of America, Joe Smith, Northwest Natural Gas Co.,

(Continued on Page 71)

### Trouard Will Represent NACE on ASCE Committee

S. E. Trouard, corrosion engineer for New Orleans Public Service, Inc., has been appointed NACE's official representative of the American Society of Civil Engineers Committee on Pipeline Crossings of Railroads and Highways. He is also representative for the American Gas Association Operating Section's Corrosion Committee on the ASCE Committee.



The ASCE Committee is charged with the responsibility of writing proposed specifications for pipeline crossings of railroads and highways that will be recommended to the American Standards Association for adoption into a standard code.

### Friend Appointed NACE Representative for ASA

W. Z. Friend of International Nickel Co., Inc., New York City, has been appointed NACE's representative on the American Standards Association Sectional Committee N-5 on Chemical Engineering in the Nuclear Field.



The appointment came as a result of an invitation from American Standards Association for NACE to participate in the Sectional Committee deliberations, according to Hugh P. Godard, NACE president.

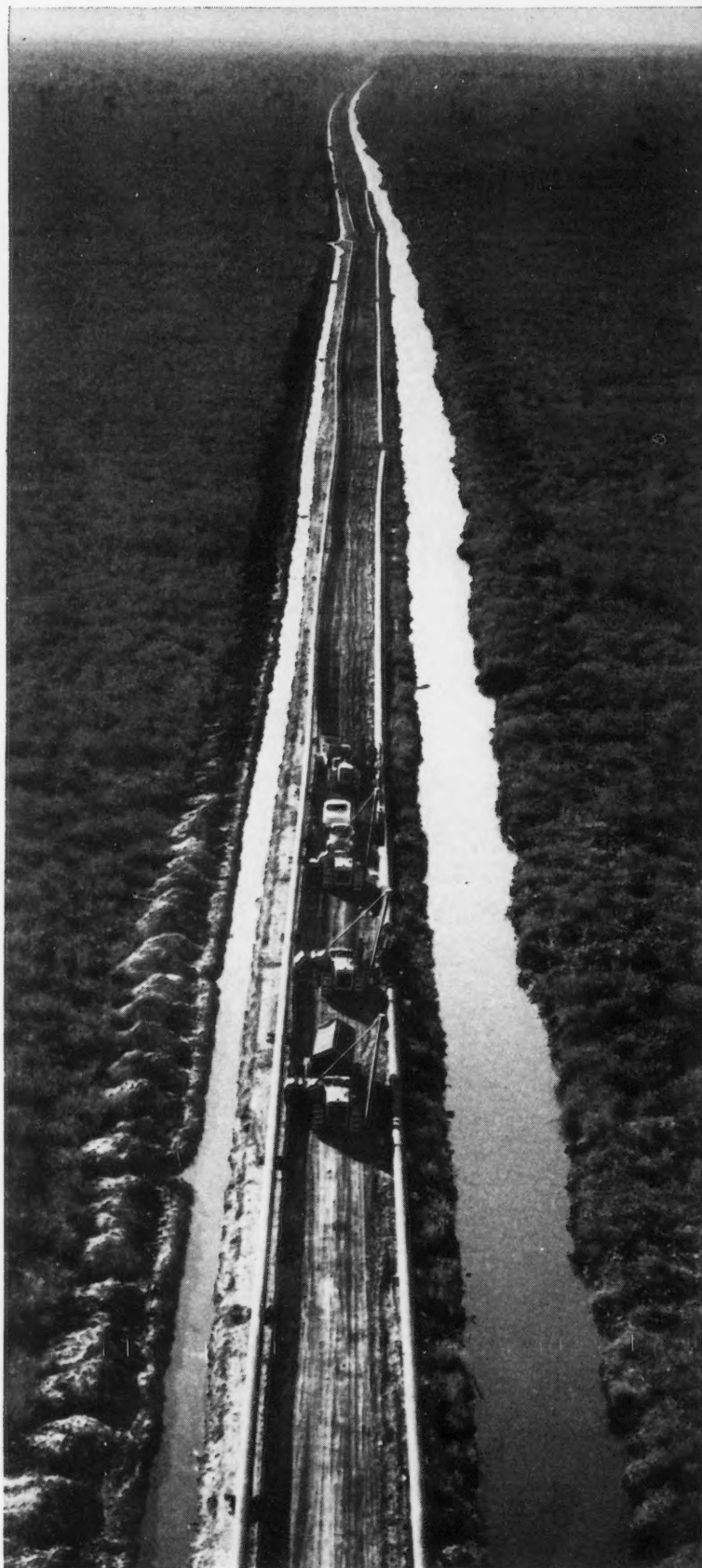
### Rutter Heads Committee To Plan Short Course

C. M. Rutter, chief corrosion engineer of the Equitable Gas Co., Pittsburgh, Pa., is general chairman for the 1960 Appalachian Underground Corrosion Short Course scheduled for June, 1960, at West Virginia University, Morgantown, W. Va.



A meeting of the short course General Committee was held December 3 at the Penn-Sheraton Hotel in Pittsburgh, Pa.





## HOW TO CHECK OUT THE TOUGHEST TAPE EVER WRAPPED AROUND PIPELINE

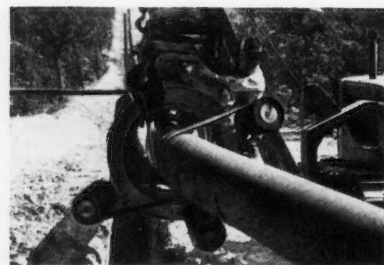
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Polyken did to its latest development—  
Extra Strength No. 960

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## South Central Region News

### POLYKEN PROTECTIVE COATINGS DISTRIBUTORS

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Steele & Associates, Inc.

**Chicago, Illinois**  
Sales Engineering Inc.

**Cincinnati, Ohio**  
Hare Equipment

**Cleveland, Ohio**  
The Harco Corp.

**Denver, Colorado**  
Patterson Supply

**Des Moines, Iowa**  
Donald Corporation

**Fort Worth, Texas**  
Plastic Engineering & Sales Corp.

**Harvey, La.**  
Allen Cathodic Protection  
Company, Inc.

**Houston, Texas**  
Cathodic Protection Service

**Kansas City, Missouri**  
Industrial Coatings Engineering Co.

**Long Beach, Calif.**  
Barnes & Delaney

**Memphis, Tenn.**  
General Pipe & Supply Co.

**Minneapolis, Minn.**  
Simcoe Equipment Co.

**Philadelphia, Pa.**  
Harold N. Davis Co.

**Plainfield, New Jersey**  
Stuart Steel Protection Corp.

**St. Louis, Missouri**  
Shutt Process Equipment Co.

**San Francisco, Calif.**  
Incandescent Supply Co.

**San Francisco, Calif.**  
Phillips & Edwards Electric Co.

**Seattle, Washington**  
Farwest Corrosion Control Corp.

**Seattle, Washington**  
Pacific Water Works Supply Co.

**Polyken**  
Experienced in modern  
PROTECTIVE COATINGS

### Tulsa Section Sponsors 11th Annual Short Course

The 11th Annual Corrosion Short Course for Pipeliners sponsored by the Tulsa Section will be held in Tulsa Feb. 24-26, with headquarters at the Mayo Hotel, according to Paul Fisher, chairman of the Short Course Committee.

The three-day course, covering practical control of pipeline corrosion, is planned specifically for foremen, superintendents, field and junior engineers, technicians and inspectors. Experienced corrosion engineers will give non-technical presentations on the causes of corrosion, measurements and instrumentation, pipe coatings, galvanic anodes, impressed currents and miscellaneous corrosion control devices.

Corrosion engineers who will conduct lectures and discussion periods include Frank Harris, Service Pipe Line Co., Orville Everett, Oklahoma Natural Gas Co., Melvin Barb, Kerr-McGee Oil Industries, Inc., T. L. Canfield, Cathodic Protection Service, L. G. Maddox, Continental Pipe Line Co., W. A. Hutchison, Sinclair Pipe Line Co., Louis Hayward, Mid-Continent Pipe Line Co., and B. H. Davis, Gulf Refining Co.

The \$15 registration fee covers a banquet and transportation to demonstration sites. Registration forms or further information may be obtained from Ray Amstutz, Box 4597, Tulsa, Oklahoma.

Other officials of the course are Dick Walton, Royston Laboratories, program chairman; Gene Donaldson, Pan American Research Center, arrangements; Hugh Brady, Corrosion Services, Inc., registration; Louis Hayward, Jr., Mid-Continent Pipe Line Company, field trip and A. Z. Partain, Pittsburgh Coke & Chemical Company, banquet.

### Central Oklahoma Section Plans 1960 Short Course

Plans are underway for the 1960 Corrosion Control Short Course to be held September 28-30 by the Central Oklahoma Section and the Extension Study Center of the University of Oklahoma.

The course is designed to meet the needs of industrial personnel, both engineering and operating, who are concerned with corrosion control and to help train new personnel in corrosion control fundamentals.

**North Texas Section** will have Jack P. Barrett of Pan American Petroleum Company as guest speaker at the December 14 meeting. He will speak on application of plastics in the oil and gas industry.

W. C. Koger of Cities Service Oil Company spoke on testing mixed sucker rod strings at the November 9 meeting.

At the October 19 meeting, Allan Shell of Mobil Producing Company's Research Laboratory spoke on cooling water corrosion and treatment.

**Alamo Section** had a program on instrumentation as applied to corrosion testing at the October 20 meeting. The techni-

cal program was conducted by the Wayne Broyles Engineering Corp., Houston.

**Corpus Christi Section** showed the NACE film "Controlling Corrosion" at its October 27 meeting.

**East Texas Section** held a discussion on corrosion problems in producing wells at its October 27 meeting.

**Houston Section** heard John W. Nee of Briner Paint Mfg. Co., Inc., Corpus Christi, speak on the effect of atmospheric environment on corrosion rates of steel at the November 10 meeting.

**Shreveport Section** had David M. Upbe-graff, Minnesota Mining & Manufacturing Co., St. Paul, Minn., speak on microbes and corrosion at the November 3 meeting.

### LaQue to Address Joint NACE-ASTM Meeting Feb. 9

F. L. LaQue, International Nickel Co., Inc., president of the American Society for Testing Materials, will address a joint meeting of Southwest District ASTM and Houston Section NACE February 9. Mr. LaQue, formerly a president of NACE will speak on "Research in Corrosion."

### Canadian Region News

**Edmonton Section** heard E. T. Thompson of the Sherwin-Williams Company speak on proper selections, use and performance of maintenance coatings at the October 22 meeting.

Canadian Region's Eastern Division Conference will be held January 17-20 in Toronto.

Canadian Region's Western Division Conference will be February 10-12 in Vancouver.

### Portland Section—

(Continued From Page 69)

Chet Elston, Pacific Power & Light Co., and G. F. Eppley, Electrolytic Products Co.

Publicity Committee: Chairman Chal Larson, Sheldon-Dunning, Inc., Dean Burgan, Electric Steel Foundry, Robert Baynham, Dearborn Chemical Co., and Clyde Novak, Northwest Protective Coatings.

Registration Committee: Chairman Curtis Lund, Pacific Telephone & Telegraph, Gene Walthal, Electric Steel Foundry, Robert Baunach, Henry Messenger, Pacific Telephone & Telegraph, and William Scarborough, Bonneville Power Administration.

Printing Committee: Chairman Dan Boone, W. P. Fuller & Co., Keene Shogren, Northwest Natural Gas Co., Del Brown, Portland General Electric Co., John Moeller, School District No. 1, and Jack Malmquist, W. P. Fuller & Co.



THIRTY TECHNICAL PAPERS presented at the 4th Annual North Central Region Conference included one "Chemically Modified Coal Tar Coatings," by Francis R. Charlton, shown above, from Koppers Company, Verona, Pa.

## North Central Region News

### Technical Meetings Are Well Attended At October Conference in Cleveland

Technical meetings at the 4th Annual North Central Region Conference were well attended with many of them crowded. The conference was held October 20-22 at the Statler Hilton Hotel in Cleveland, Ohio. Total attendance was about 300.

Thirty technical papers on various corrosion control subjects were presented in five symposia. Five plants were visited as part of the conference program.

The so-called Russian expert, Louis Revnyak, entertained the large noon

luncheon held October 21 with his humorous dissertation on the Russians and their "firsts."

Six NACE Technical Committees held meetings during the conference. These included T-6F, T-6H, T-5D, T-2L, T-5C-2 and T-7B.

The 1960 North Central Region Conference will be held October 1920 at the Schroeder Hotel in Milwaukee, Wis.

Southwestern Ohio Section prepared a small printed card for its members with all the meeting dates, speakers and technical program topics for 1959-60.

With no meeting scheduled this month, the section will hear Robert Pierce, Pennsalt Chemical Corp., speak on corrosion resistance and masonry construction at the January 26 meeting to be held in Cincinnati.

James Myers of Wright Air Development Center spoke on applications of refractory metals in space technology at the November 24 meeting in Dayton.

Corrosion inhibitors were discussed by Jerry Alert, General Electric Co., at the October 27 meeting held in Cincinnati.

Chicago Section scheduled Walter H. Bruckner, metallurgical engineering research professor at the University of Illinois, to talk on the effectiveness and problems of cathodic protection at the November 17 meeting.

Kansas City Section had Joe H. Pitts, Standard Magnesium Anode Corp., speak on the manufacture and design of magnesium anodes for the November 9 meeting.

Eastern Wisconsin Section scheduled a talk by G. A. Stein of A. O. Smith Corp., for its November 9 Technical meeting. His talk was titled "Why Plastics?"

Detroit Section held its October 29 meeting at the Stroh Brewery Company plant. A trip through the plant was followed by a discussion by the maintenance superintendent on brewery corrosion problems. A buffet luncheon was served also.

## Northeast Region News

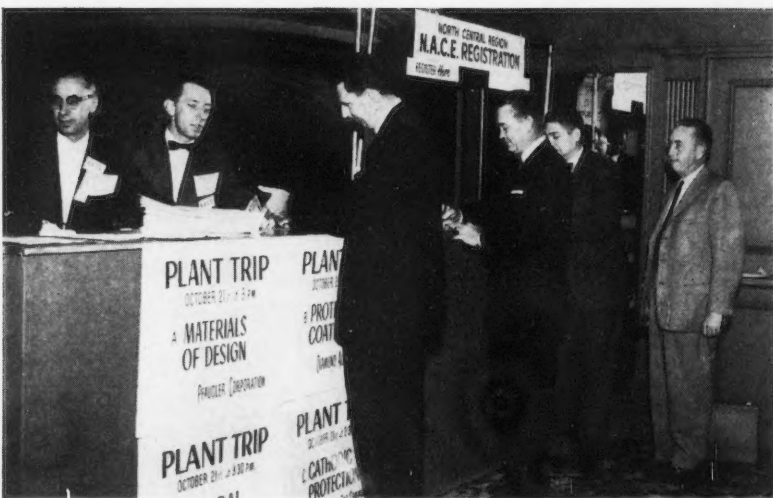
Philadelphia Section has scheduled its annual Christmas meeting for December 15. Norm Neilson of Du Pont will speak on modern research techniques applied to corrosion problems.

Kenneth Tator spoke on standards of surface preparation for coatings at the section's October 23 meeting.

Wilmington Section had Wayne Friend of International Nickel Co., Inc., speak on general corrosion problems in the chemical and petroleum industries at the November 16 meeting.

PROPERTIES	AMINE EPOXY	EPOXY ESTER	VINYL	PARLON	ALKYDS
CHEMICAL RESISTANCE	EXCELLENT	GOOD	EXCELLENT	FAIR	POOR
ACIDS	EXCELLENT	GOOD	EXCELLENT	FAIR	POOR
ALKALI	EXCELLENT	GOOD	EXCELLENT	FAIR	POOR
SOLVENTS	EXCELLENT	GOOD	EXCELLENT	FAIR	POOR
PHYSICAL PROPERTIES					
FLEXIBILITY	GOOD	EXCELLENT	EXCELLENT	GOOD	GOOD
ADHESION	EXCELLENT	EXCELLENT	EXCELLENT	GOOD	GOOD
HARDNESS	EXCELLENT	EXCELLENT	EXCELLENT	GOOD	GOOD
ABRASION RESISTANCE	EXCELLENT	EXCELLENT	EXCELLENT	GOOD	GOOD
APPLICATION METHODS					
SOLIDS AT SPRAY VISCOSITY	S.B.R.	S.B.R.D.	S.B.R.D.	S.B.R.D.	S.B.R.D.
PROMINENT CURAB	55	50	25	30	50
AVERAGE THICKNESS	40	35	10	15	40
MILS	1.0 TO 2.0	1.0	0.4	0.8 TO 0.4	15 TO 1
CURE OF COATINGS	CHEMICAL CURE	OXIDATION	SOLVENT EX	SOLVENT EX	OXIDATION
GOOD RETENTION	POOR	FAIR	EXCELLENT	FAIR	EXCELLENT
COLOR RETENTION	FAIR	GOOD	EXCELLENT	FAIR	EXCELLENT
* SPRAY	BRUSH	ROLL	FLOW	DIP	

PROTECTIVE COATINGS SYMPOSIUM included a paper on "Epoxy Resin Protective Coatings," by N. A. Mason of Pittsburgh Plate Glass Co., Pittsburgh, Pa., presented at the 1959 North Central Region Conference.

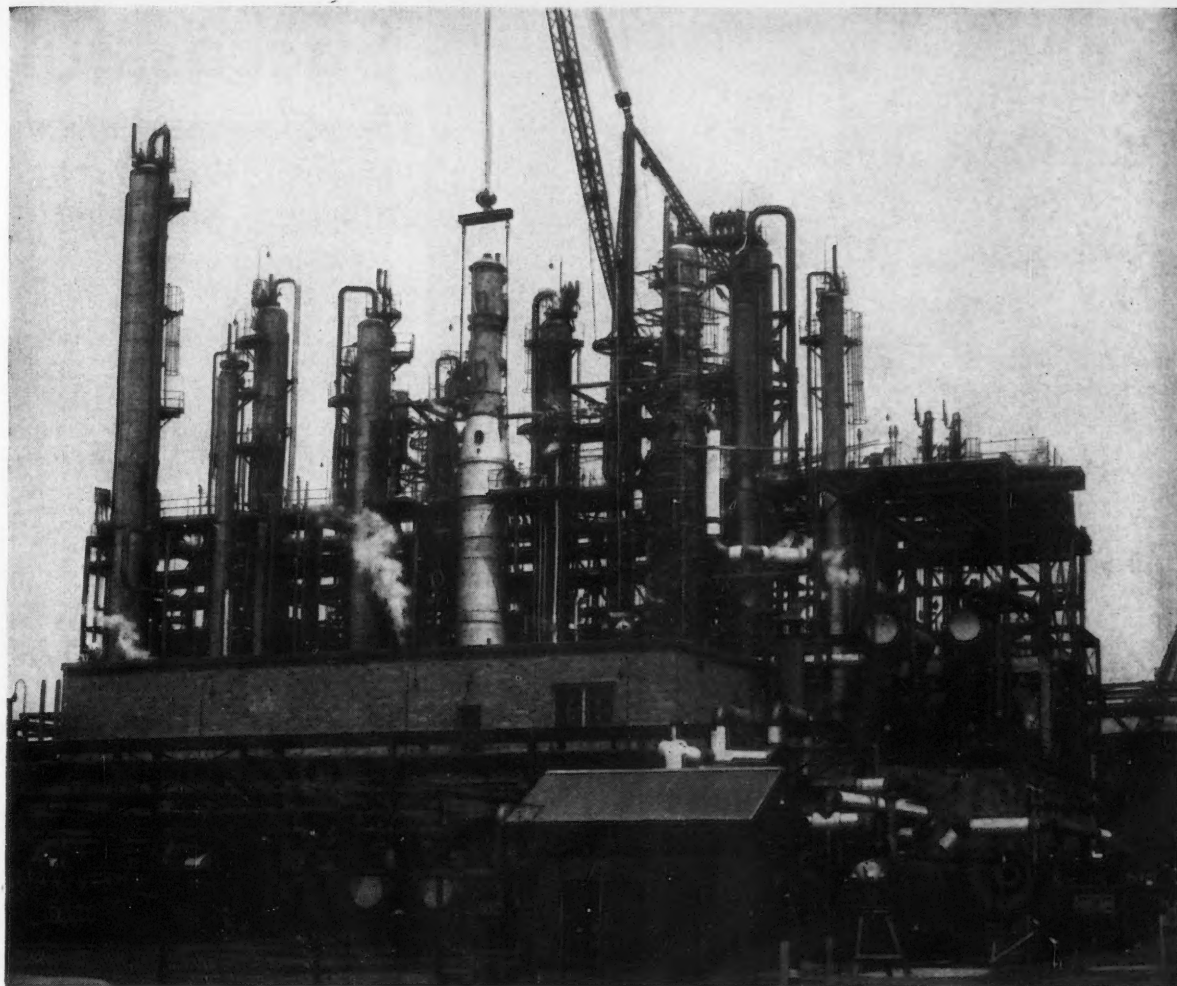


CONFERENCE REGISTRANTS are shown getting tickets to attend the five plant visits which were scheduled as part of the North Central Region Conference. About 300 attended the conference in Cleveland.

### NEWS DEADLINE FOR CORROSION

News intended for publication in CORROSION should be in Houston not later than the 10th of the month preceding month of publication. When events occur at or near this date, it sometimes is possible to hold space for news stories, provided advance notice is given. An estimate of the amount of space required should be included in the advance notice.





Erecting the all-welded, two-part chromium-nickel stainless steel recovery tower at Gary chemical works of United States Steel Corpora-

tion. Graver Tank & Mfg. Co., Inc. of East Chicago, Indiana, fabricated the 90-foot tower and tested it to pressures of 162 psi and 246 psi.

## Stainless steel tower goes up...corrosion comes down... in recovery of aromatic chemicals from coke oven gases

**This chromium-nickel stainless steel tower** recently took over an important job at the Gary Steel Works Coke & Coal Chemicals Div. of U. S. Steel. The big vessel receives hot absorption oils from other parts of the processing plant . . . puts them through its six-tray light oil section, and 15-tray light oil stripper . . . recovers benzene, toluene, and xylene.

**It's a productive but highly corrosive process.** So corrosive that it


knocked out a carbon steel tower in relatively short time. That's why for its replacement the Gary Works decided on Type 304 ELC chromium-nickel stainless steel. This nickel-containing stainless steel can take the corrosive effects of these gases and chemicals . . . it assures *long* service life.

**For your corrosion problems,** it will pay you to consider nickel-containing stainless steels. They are highly re-

sistant to a wide range of organic and inorganic chemicals.

\* \* \*

**A 34-page booklet, "Corrosion Resisting Properties of the Austenitic Stainless Steels,"** is available to you upon request. If you'd like a copy, simply write:

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## Two Chairmen Named To Head Work on Plastic Coated Pipe

Chairmen were named for two committees to be composed of persons interested in plastic coated pipe used in the petroleum industry at a meeting of T-1 in Denver. The meeting was one of 17 scheduled for technical committees at the 1959 South Central Region Conference held October 12-15. One committee, headed by Dorsey R. Fincher, Tidewater Oil Company, Houston, Texas, will be composed of pipe users; the other headed by Patrick R. Donnelly, Plastic Applicators, Inc., Houston, Texas, will be composed of pipe producers.

The aim is to coordinate the activities of both groups so that producers will have better information on users' needs and users will have more reliable information on producers' products.

This group, one of several initiated under the proposed reorganization of T-1, is to make its first report at the March NACE National Conference in Dallas.

### Inhibitor Squeeze Results

Reporting on data collected on inhibitor squeeze results, R. H. Poetker, Sunray Oil Corp., Corpus Christi, Texas, said reports have been received on 300 wells using 32 chemicals, 92 percent of which had successful results. Significant among the findings indicated by the reports, he said, was the fact that the kind and quality of the diluent used for the inhibitor was important to its success. It also was learned that applications after the first appeared to give better results than the initial application.

T-1 on Corrosion in Oil and Gas Well Equipment sessions lasted all of Monday, October 1, most of Tuesday and part of Wednesday. During this time numerous reports of committees and their task groups were heard and discussed, and considerable time was spent considering the proposed reorganization of the committee's structure.

Among topics considered during the meeting were terminology problems in connection with interference studies on cathodic protection systems on oil well casings, and tools for the detection of external corrosion on oil well casings.

**TECHNICAL MEETINGS** held at the recent South Central Region Conference in Denver are shown. Photo One: Fred B. Hamel of Standard Oil Co., Cleveland, Ohio, who is chairman of Technical Committee T-8A, is shown talking before the T-8 group. Seated at the table, left to right, are T-8 officers: Secretary R. L. Merrick, Esso Research & Engineering Co., Linden, N. J., Chairman E. B. Backensto, Socony Mobil Oil Co., Inc., Paulsboro, N. J., and Vice Chairman Cecil Phillips, Jr., Humble Oil & Refining Co., Baytown, Texas. Photo Two: T-6D-1 Chairman S. L. Lopata, Carboline Co., St. Louis, Mo., is giving a report at the T-6D meeting. Seated at the table are T-6D Chairman R. H. Bacon, Dow Chemical Co., Freeport, Texas, and Acting Secretary F. Parker Helms, Union Carbide Chemicals Co., Texas City, Texas. Photo Three: Frank B. Burns, General Asphalts, Inc., Wynnewood, Okla., opens the Pipe Line Corrosion Symposium. Photo Four: T-2B Chairman Richard J. Emerson, El Paso Natural Gas Co., El Paso, Texas, presides at the T-2B meeting. Photo Five: Protective coatings in petroleum production are being discussed at the T-6E meeting with C. J. Fritts, Socony Paint Products Co., Houston, Texas, as chairman.

# Conference Held at Denver



NACE PRESIDENT-ELECT George E. Best was presented a ten-gallon hat, emblematic of acceptance into the brotherhood of the West. J. A. Caldwell, Humble Oil & Refining Co., Houston, Texas, made the presentation.

## About 600 Attend Busy Sessions at Regional Meeting

A smoothly functioning, business-like program made the October 12-15 Thirteenth Annual Conference of NACE's South Central Region worthwhile to almost 600 registrants. Of these, some 75 were women, attracted to the scenic beauties of the fall countryside in Colorado. A well-organized and completely satisfying social program was carried on during the meeting. The ladies' program was especially interesting and drew wide participation.

The program, arranged so that the program of technical committees meetings and the technical symposia were virtually separated, attracted good attendance at most sessions. Registration proceeded without undue delay.

In addition to the technical and social programs, numerous business sessions of regional groups were held. Among these was the annual business luncheon, attended by about 400 persons, at which regional officers and national officers were introduced. Also held were meetings of the regional board of trustees and the region's education committee. Both of these sessions were attended by representatives groups.

A three-man vocal and instrumental act was featured as entertainment at the annual banquet, and this was followed by dancing.

Besides the usual business of the luncheon, the region took the opportunity to present to Vice President George E. Best, incumbent 1960-61 president of NACE, a ten-gallon hat emblematic of his acceptance by the brotherhood of the West. An address by Chester Lauck, executive assistant, Continental Oil Co., formerly the "Lum" of radio's Lum and Abner team, concerned the necessity for business and businessmen to take active part in politics. Mr. Lauck stressed the importance

of getting the business viewpoint effectively presented to the public and effectively represented on political bodies.

## J. A. Caldwell Appointed To Board of Directors

J. A. Caldwell, senior research engineer for Humble Oil and Refining Company, Houston, Texas, was appointed to the NACE Board of Directors to represent the South Central Region. He will fill the unexpired term of the late J. C. Spalding.

The appointment was made at a meeting of the South Central Region Board of Trustees held during the region's conference in Denver, Oct. 12-15.

## Several Denver Meetings Had "Standing Room Only"

Most meetings of technical committees held during the Denver Conference in October were well attended. Some meetings were so crowded there was not even standing room left, and many who tried to be present could not get into the meeting rooms. This resulted in part from larger than anticipated attendance and in part from the fact that available meeting rooms were limited in size.

Some companies took advantage of the presence at the meeting of representative attendance from their companies to hold meetings devoted to company business.

## Technical Tours Held

Technical tours arranged for the Denver meeting were well attended, especially the Engineering Laboratories of the Bureau of Reclamation. The Ohio Oil Company's Research Center also was visited by two groups.

## Annual Fellowship Hour

The annual Fellowship Hour, attended by more than 600 persons was, as is the custom, the best attended function of the Denver South Central Region meeting.



### TECHNICAL REPORTS on

### Marine Biological Deterioration

T-9 Observations on the Resistance of Natural Timbers to Marine Wood Borers. A Contribution to the Work of Group Committee T-9 on Marine Biological Deterioration, by C. H. Edmondson. Pub. 58-14, Per Copy \$.50.



HOSTESSES for the ladies' program at the Denver Conference were Mrs. William P. Becker (standing) and seated, left to right, Mrs. H. K. Becker and Mrs. Herbert L. Goodrich.



DANCERS rest a few minutes following the South Central Region annual banquet at Denver.



# Corrosion of Anodic Surfaces Is Controlled by Electrical Method

Instrumentation which permits controlling corrosion of anodic surfaces by application of electrical currents of very small magnitude has been developed by a team of researchers in the Ponca City laboratories of Continental Oil Company. Their discovery and extensive data on its practical use, as well as some estimates of the importance of their method, were described in three technical papers during the Denver conference of NACE's South Central Region.

The three papers in the Refining and Chemical Process Industries Symposium presented during the afternoon of October 14 were Anodic Passivation Studies by J. D. Sudbury, O. L. Riggs and D. A. Shock; Anodic Control of Corrosion in a Sulfonation Plant by O. L. Riggs, M. Hutchinson and N. L. Conger; and Application of Anodic Corrosion Control in the Chemical Industry by Shock, Riggs and Sudbury.

## Far Reaching Effect Seen

Application of the new method may have a far reaching effect on the selection of materials for design of vessels handling corrosive fluids, especially those at temperatures to 500° F. A potential regular developed by the research team permits controlling corrosion of anodic surfaces through the application of very small currents. Geometry of the surface apparently has no influence on the efficiency of the system, experiments having shown that 60 feet of stainless steel tubing could be protected from a single cathodes even though the system included numerous right angle and other bends.

Although the nature of the passive layer formed on the anodic surface is not clearly defined, data so far obtained indicate it is a very thin oxygen-containing amorphous film with a resistance in the order of  $10^4$  to  $10^6$  ohms per square centimeter. This passive layer can be maintained by the application of small increments of current once the passive state has been reached.

## Developed From Flade Effect

That such a method of controlling corrosion is possible has been known for some time. The discovery by Flade in 1911 that steel in sulfuric acid reached a passive state following the application of definite current values over a short time is a well known fact. The research team, proceeding on the assumption that modern instrumentation would make possible a satisfactory system today where earlier researchers had failed, managed to develop a device which permits reaching the passive state quickly, and then maintaining the passive state over a wide variety of temperatures, concentrations and velocities with very little current drain.

D. A. Shock, one of the members of the research team, in discussing the work pointed out that the Conoco development, designated as the "Anotrol" method, is an example of successful use of a discovery made by a researcher concerned only with so-called "pure science." "Development of a reliable and simple means of adding current increments to the anode in sufficient quantity to maintain the continuity of the oxy-

gen-metal passive layer made the Anotrol method practical," he said.

## Tested at Baltimore

The automatic potential controller and other aspects of the process were tested at the Baltimore, Md., sulfonation plant of Continental Oil Co. There it was proved that the device would reduce to negligible proportions corrosion of a mild steel oleum storage tank and a Type 304 stainless steel sulfonic acid neutralization vessel. Tests over a year showed good protection, measured in reduced iron concentration, improved product quality resulting from absence of iron salts and increased productivity in the plant due to more rapid hydrocarbon separation resulting from absence of iron soaps.

Opportunity was taken during these tests to evaluate the effect of such variables as concentration, changes in surface area, temperature, effect on a variety of metals and effects of a variety of chemical environments.

Application of the process to an oleum storage tank resulted in reduction of iron content from 500 to 600 ppm to 39 to 41 ppm; in a blowcase tank from 550 ppm to 59 ppm in 10 days.

## Stress Corrosion Cracking

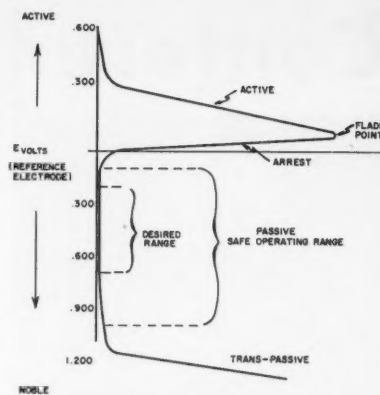
The researchers are making studies on the possibility of stress corrosion cracking resulting from the use of the system especially at high stress values. The four years of work has shown no evidence so far that stress corrosion cracking will occur, although some vessels have been passivated repeatedly in a variety of environments. No evidence of stress corrosion was noted in the vessels to which the process was applied at the sulfonation plant. These vessels have been operated at relatively low stress levels.

Ultimate uses of the system are assessed in the third paper of the series. In this paper it is brought out that the two major factors for a successful anodic mitigation system are (1) the solution must be a good conductor and (2) the metal-liquid system must be such that it exhibits the phenomena of anodic passivity.

Virtually all water solutions of the oxy-acids, the bases and oxy-acid salts are suitable. Emulsions of strong sulfuric acids and hydrocarbons have been found sufficiently conductive (up to 80 percent oil). Major exclusions are solutions containing halogen radicals which destroy passivity to such an extent that anodic passivation becomes either uneconomical or altogether impossible.

Numerous data were compiled to show the current density required to maintain the passive state of the anode. An analysis of the data sometimes make possible an estimate of cost which can influence the decision between alloys or between alloys and steel as a material of construction for specific product streams.

Among the environments in which the process may find application are those involving the handling of nitrate and sulfate salts, some of the fuel element uranium processes and in such applications as alkaline digesters in the paper pulp industry.



TYPICAL ANODIC polarization curve. (Figure 1 from paper, "Anodic Control of Corrosion in a Sulfonation Plant".)



## SECTION CALENDAR

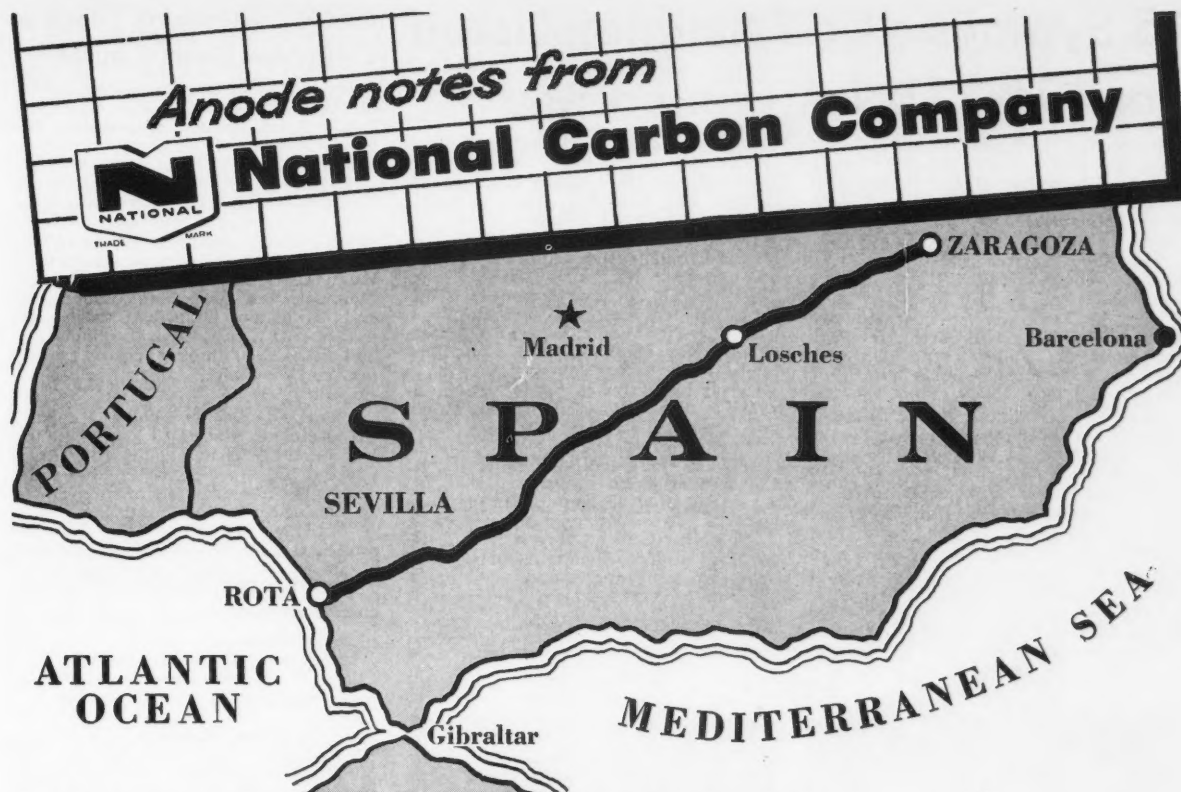
### December

- 1 Shreveport Section. Capt. Shreve Hotel. Plant Corrosion.
- 3 West Kansas Section.
- 3 Sabine-Neches Section
- 3 Pittsburgh Section. Underground Roundtable. Discussion by six speakers.
- 3 Teche Section. Petroleum Club.
- 4 Birmingham Section.
- 7 North Texas Section.
- 8 San Francisco Bay Area Section.
- 15 East Texas Section. Longview Hotel in Longview.
- 15 Philadelphia Section.
- 29 Panhandle Section.

### January

- 4 North Texas Section.
- 5 Shreveport Section. Capt. Shreve Hotel.
- 7 West Kansas Section.
- 7 Pittsburgh Section. Microbiological Studies of Pipeline Back-Filled Ditches, by J. O. Harris, Kansas State University.
- 12 San Francisco Bay Area Section.
- 12 Baltimore-Washington Section.
- 19 Chicago Section.
- 20 Los Angeles Section.
- 21 Detroit Section. Tank Lining Forum: L. Woerner, Automotive Rubber Co., L. J. Barker, Union Carbide, and W. J. Crehan, Gatz.
- 25 Tulsa Section.
- 26 Panhandle Section.
- 26 Southwestern Ohio Section. Corrosion Resistant and Masonry Construction, by Robert Pierce, Pennsalt Chemical Corp. To be held in Cincinnati.
- 28 Edmonton Section.
- 28 Sabine-Neches Section.

Lapel pins approximately 7/16 inches high, made of gold with inlaid red enamel and a ruby center, are available to NACE members only. Price is \$10. Address orders to Executive Secretary, 1061 M & M Bldg., Houston 2, Texas.



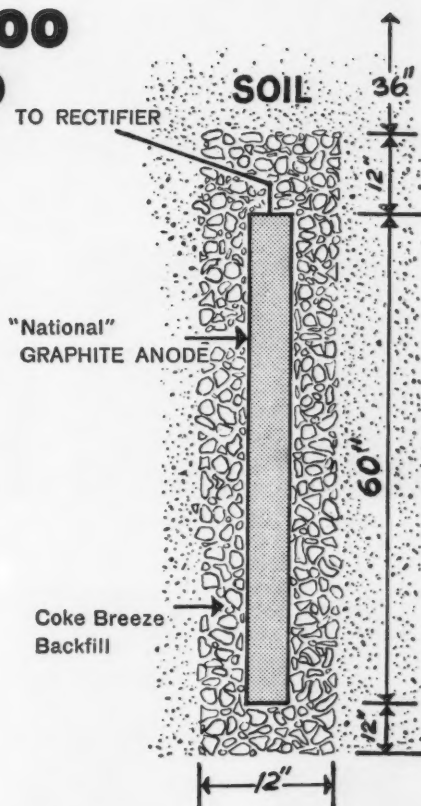
## PROTECTION OF 11,000,000 SQ. FT. OF UNDERGROUND STEEL IN SPAIN

"National" graphite anodes for cathodic protection are used around the world. In 1958 four-hundred-sixty 3"x60" "National" graphite anodes\* were installed to protect the 620 mile Spanish J.U.S.M.G. pipeline from Rota to Zaragoza. The 12", 10", 8" and 6" diameter coated steel pipeline with attendant service pipelines of varying diameters, plus twenty-six tank bottoms total approximately 11,000,000 square feet of steel under cathodic protection.

Because of the wide variations in soil resistivity along the pipeline, each anode and rectifier installation had to be individually engineered. Twenty-six rectifiers with outputs ranging from 20 volts DC to 200 volts DC, from 40 amps to 100 amps were used.

The graphite anodes were placed on 20 foot centers in 12" diameter x 120" deep holes surrounded by well tamped coke breeze backfill. The number of anodes in each bed varied, depending upon the current discharged and the soil resistivity. The system is designed to operate for more than ten years.

\*Wayne Broyles Engineering Company supplied the equipment and installed the cathodic protection system.



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## 15 Symposia Co-Chairmen Listed For 1960 Dallas Conference

Fifteen co-chairmen of the technical symposia for the 1960 NACE Conference have been named. The 16th Annual Conference will be held March 14-18 at the Memorial Auditorium in Dallas, Texas.

The 1960 Corrosion Show will be held in conjunction with the Dallas Conference.

The 15 symposia co-chairmen are listed below. They will be chairmen for the technical symposia for the 1961 NACE Conference to be held in Buffalo, N.Y.

The Pulp and Paper Industry Symposium has been postponed until the 1961 Conference in Buffalo.

Cathodic Protection: O. W. Everett, Oklahoma Natural Gas Co., Tulsa, Okla.

Chemical Industries: Otto H. Fenner, Monsanto Chemical Co., St. Louis, Mo.

Corrosion in the Missile Industry: Edison H. Phelps, U. S. Steel Corp., Monroeville, Pa.

Corrosion Inhibitors: Donald L. Burns, Gulf Oil Co., Port Arthur, Texas.

Corrosion Principles: C. P. Dillon,

Union Carbide Chemicals Co., Charleston, W. Va.

Educational Lectures: Norman D. Groves, Carpenter Steel Co., Reading, Pa.

Elevated Temperatures: David Roller, Magna Products, Inc., Santa Fe Springs, Cal.

General Corrosion: Jerome M. Bialosky, Koppers Co., Inc., Verona, Pa.

High Purity Water: W. K. Boyd, Battelle Memorial Institute, Columbus, Ohio.

Oil and Gas Production: J. A. Caldwell, Humble Oil & Refining Co., Houston, Texas.

Pipe Line—General: Carleton L. Goodwin, Portland Pipeline Corp., Portland, Maine.

Plastics: John Delmonte, Furane Plastics, Inc., Los Angeles, Cal.

Protective Coatings: Newell B. Casdorph, Union Carbide Chemicals Co., Port Lavaca, Texas.

Refining Industry: R. B. Hamel, Standard Oil Co., Cleveland, Ohio.

Utility Industries: A. W. MacKay, Detroit Edison Co., Detroit, Mich.

## 6 NACE Members Teach at California Short Course

Six NACE members were on the staff of the University of California's Short Course on Corrosion Engineering held November 2-6 on the Los Angeles campus. They were William Seyer, professor of engineering, University of California; Norman Hackerman, chairman, Department of Chemistry, University of Texas; H. H. Uhlig, professor of metallurgy, Massachusetts Institute of Technology; Hugh P. Godard, NACE president associated with Aluminium Laboratories Ltd., Kingston, Ontario, Canada; Willard R. Scott, Jr., Magna Products, Inc., and C. M. Schillmoller, corrosion engineer and consultant, International Nickel Co., Inc.

The course was designed to emphasize the problems associated with high and low humidity change in marine atmosphere of the Pacific coast region and to review the fundamentals of corrosion reactions and corrosion control.

### Southeast Region News

Atlanta Section held a dinner meeting on November 16. Guest speaker was K. G. Compton of Bell Telephone Laboratories, Summit, N.J.

East Tennessee Section had Norman Hackerman, chairman of the University of Texas Department of Chemistry, as its guest speaker at the October 22 meeting held in Oak Ridge. Dr. Hackerman's address was titled "Mental Dissolution and Its Retardation."

The 1960 Southeast Region Conference will be held Oct. 6-8 at the Dinkler-Plaza Hotel, Atlanta, Ga.

Portland Section's Corrosion Control Short Course will be held April 27-29.



Bialosky



Boyd



Burns



Caldwell



Casdorph



Delmonte



Dillon



Everett



Fenner



Goodwin



Groves



Hamel



MacKay



Phelps



Roller



**1960**

January 17-20—Canadian Region Eastern Division. Toronto, King Edward Hotel.

February 10-12—Canadian Region Western Division. Vancouver. Hotel Georgia.

March 14-18—16th Annual Conference and 1960 Corrosion Show. Dallas, Texas, Memorial Auditorium.

Oct. 6-7—10th Annual Western Region Conference, Sheraton-Palace Hotel, San Francisco, Cal.

Oct. 6-8—Southeast Region Conference, Dinkler-Plaza Hotel, Atlanta, Ga.

Oct. 11-14—Northeast Region Conference, Prichard Hotel, Huntington, W. Va.

Oct. 19-20—North Central Region Conference. Schroeder Hotel, Milwaukee.

Oct. 25-28—South Central Region Conference, Mayo Hotel, Tulsa.

**1961**

March 13-17—17th Annual Conference and 1961 Corrosion Show, Buffalo, N. Y., Hotel Statler.

Oct. 4-6—Western Region Conference, Hotel Multnomah, Portland, Oregon.

Oct. 9-11—North Central Region Conference, St. Louis, Chase Park Plaza Hotel.

Oct. 24-27—South Central Region Conference, Houston, Shamrock Hotel.

Oct. 30-Nov. 2—Northeast Region Conference, New York City, Hotel Statler.

Southeast Region Conference, Miami, Fla., in conjunction with Miami Section's short course.

**1962**

March 18-22—18th Annual Conference and 1962 Corrosion Show. Kansas City, Municipal Auditorium.

October 9-11—North Central Region Conference.

October 16-19—South Central Region Conference, Hilton Hotel, San Antonio, Texas.

Southeast Region Conference, Birmingham, Ala.

Western Region Conference. San Diego, Cal.

**SHORT COURSES****1959**

December 7-11—University of Illinois Corrosion Control Short Course. Urbana Campus.

**1960**

January 28-29—5th Annual Houston Section 2-Day Course in Practical Corrosion Control Systems. Rice Hotel, Houston.

February 24-26—11th Annual Tulsa Section Corrosion Short Course for Pipeliners. Mayo Hotel, Tulsa, Okla.

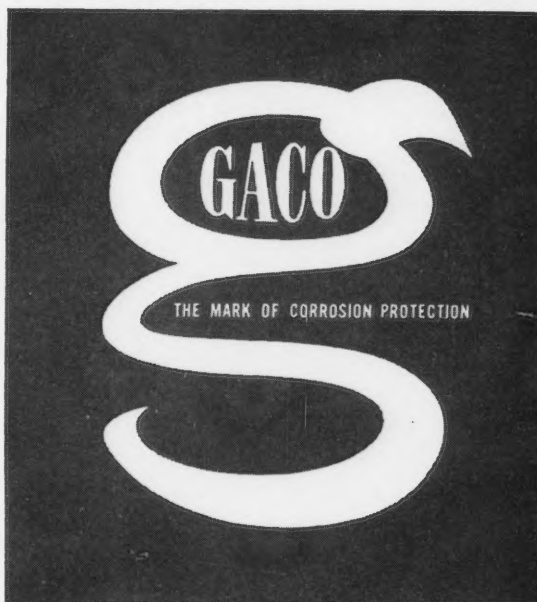
April 27-29—Portland Section Corrosion Control Short Course.

September 28-30—Central Oklahoma Section 1960 Corrosion Control Short Course, at University of Oklahoma, Norman.

October 3-5—Corrosion Control Short Course, sponsored by Western Region and University of California.

# NEW GACO V-80 HOT SPRAY VINYL

5 mils of high solids vinyl in a single spray coat and process equipment is protected against corrosive fumes and high humidity. GACO V-80 Vinyl films are hard but flexible, resist abrasion and most corrosive agents, and are easily cleaned. Hot spray technique allows deposit of a low plasticizer quick-drying film with little overspray and excellent edge buildup resistance to sagging. Write for details.



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## GENERAL NEWS

### Epoxy Resin Coatings Resist Intense Gamma Radiation

A nuclear radiation-resistant epoxy resin coating has been developed for concrete and steel which will withstand prolonged exposure to high intensity gamma radiation. The coating was used recently in the construction of the Plum Brook Reactor of the National Aeronautics and Space Administration near Sandusky, Ohio. The coating must maintain a waterproof barrier and must be capable of being decontaminated should contaminated water escape.

Resistance of the coating to radioactive bombardment was tested by exposing panels to a  $1\frac{1}{2}$  million volt electron source. Electron bombardment was used instead of the gamma radiation to which the coating will be exposed in use in order to accelerate the testing. Using gamma rays, the test would have required 1000 hours instead of the  $4\frac{1}{2}$  used. Physicists say that gamma or electron radiation produces similar damage.

Coated test panels were passed back and forth through the electron beam at 10-second intervals. After  $4\frac{1}{2}$  hours of exposure, the epoxy coating had received a dosage of  $1 \times 10^6$  rad units (roentgens). When test panels were compared with the non-exposed control panels, there was no visible damage such as cracking, flaking, bubbling or blistering. The coating also withstood over 9500 hours of attack by boiling distilled water, jet fuel and salt spray. Performance of the coating was judged satisfactory for service a few feet from the radioactive heart of the reactor.

The radiation-resistant coating is a two-part cold curing vehicle requiring a curing agent to complete the chemical reaction which hardens the resin. The same basic epoxy resin is used for the red primer coat, gray mastic coat (into which glass cloth is embedded) and the white finish coat. Coating thickness is 23 mils on the concrete, 16 mils on the steel.

The Plum Brook research reactor is housed in a 100-ft diameter airtight containment tank. Within this tank is a 70-ft diameter pool of water at the center of which will be the atomic reactor, bedded in a steel pressure vessel surrounded by a 2-ft concrete wall. The water acts as the neutron and gamma ray shield.

Branching out from the center are four concrete quadrants. They are joined by a circular concrete wall which varies in thickness from 2 to 4 feet. The new coating is designed to maintain a waterproof barrier for the containment of the water under a radiation intensity of the 60 megawatt power source.

In operation, all major experiments to be irradiated in the reactor have to be inserted through the water shield which fills the tank quadrants. At the conclusion of experiments, radioactive parts and materials will be removed from the reactor and be carried through a number of water filled canals to the "hot

laboratories" for disassembly and inspection. This method of handling atomic experiments is regarded as a new concept in high power reactor design.

When completed, the \$11 million Plum Brook Reactor will be one of the nation's largest test facilities. One major objective on the installation will be to develop reactors for space propulsion. Other projects will include element evaluation tests, basic physics studies and the results of radiation damage to materials.

The epoxy resin coating was developed jointly by the Shell Chemical Corp., New York, and the Patterson-Sargent Co., Cleveland, Ohio, coatings and paint manufacturers. Preparation, application of coating and glass cloth were done by Akron Sandblast and Metallizing Co., Barberton, Ohio.

### Belgian Corrosion Study

Pre-determination of corrosion of metals and alloys was the subject of an European study session held at the University School of Brussels, Belgium, Oct. 13.

Three papers were presented at the afternoon meeting. They were: Potential-pH Diagram; Theoretical Considerations on Corrosion, Inhibition and Passivation of Metals; and Potentiostatic Studies—Applications to Unalloyed Steels, Alloyed Steels and Aluminum. Discussions followed the papers.

An inspection tour of the university's laboratories followed the meeting. The study session was sponsored by Centre Belge d'Etude de la Corrosion, a non-profit technical association.

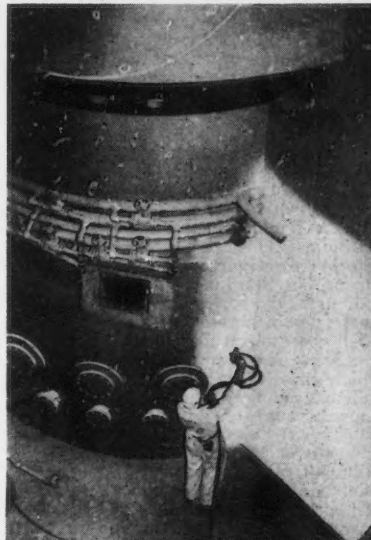
### Nace Technical Reports

**STRESS CORROSION CRACKING.** 15 papers reprinted from Corrosion. Pub. 59-4. Postpaid, per copy .....\$3

**HIGH PURITY WATER CORROSION.** Sixteen papers reprinted from Corrosion. Pub. 59-3. Postpaid, per copy .....\$3

**1957-58 NACE TECHNICAL REPORTS.** 38 reports reprinted from Corrosion. Includes some in Pub. 59-2 and 3 above. Postpaid, per copy \$6.50

Remittances must accompany all orders for literature the aggregate cost of which is less than \$5. Orders of value greater than \$5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas. Add 65¢ per package to the prices given above for Book Post Registry to all addresses outside the United States, Canada and Mexico.



**FINAL COAT** of a radiation-resisting paint is applied on concrete and steel in a quadrant of the Plum Brook Reactor, Sandusky, Ohio. Total thickness of the coating is 23 mils on concrete, 16 mils on steel.

## BOOK NEWS

**Symposium on Instrumentation in Atmospheric Analysis.** 57 pages, 6x9, cloth. May, 1959. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per copy, \$2.25.

Four papers presented at a meeting of ASTM Committee D-22 on Methods of Atmospheric Sampling and Analysis at Boston, Mass., June 23, 1958.

Persons concerned with metering atmospheric pollution will find the information in these papers helpful. Data are given on methods for continuously analyzing contents as well as for periodical measurements.

The papers are: Light Scattering Instrumentation for Particle Size Distribution Measurements, Filtration Methods for Evaluation of Aerosol Contaminants, Relative Merits of Gas Chromatography, Colorimetry and Spectrometry for Air Pollution Studies, An Atmospheric Fluoride Recorder. There are numerous references.

**Compilation of ASTM Standards Relating to Coated and Uncoated Iron and Steel Sheet and Strip, A-1, A-5.** 148 pages, cloth, 6x9 inches. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per copy \$3.00.

First compilation of ASTM standards relating to coated and uncoated iron and steel sheet and strip. There are 21 standards given including 11 specifications for steel sheet and strip, 3 specifications for metallic coated steel sheet, 2 for wrought iron sheet and one for metallic coating materials. Four test methods are given also.



## Porcelain Electrode Developed for Salt Study

A porcelain-capsule reference electrode has been developed by the National Bureau of Standards in work sponsored by the Atomic Energy Commission. This reference electrode should be of value in studying electrode potentials in molten salt systems. Accurate data on these potentials are important for investigating electrodeposition from molten salts, corrosion by molten salts, and thermodynamic properties of molten salt systems.

Reference electrodes are used widely in electrochemistry. Several types which have been used for molten salt systems are the silver-silver chloride electrode with a liquid junction, the platinum-platinum (II) electrode, the silver-silver chloride electrode in a graphite sheath for use in fluorine melts, and sodium, sodium alloy, or silver-silver chloride electrodes in glass capsules.

All these electrodes have some disadvantages. For example, those electrodes which make contact to the melt through a liquid junction are subject to fluctuations because of diffusion and mixing. Capsule-type electrodes of glass are limited to use at a maximum temperature of about 500 C. The porcelain-capsule electrode, on the other hand, is stable at temperatures as high as 900 C. Moreover, its capsule construction prevents the salt inside the electrode from contaminating the melt under study.

The porcelain reference electrode consists of an outer unit prepared by joining a glass T-tube to a porcelain capsule. Sealed inside this enclosure is an inner unit consisting of a silver wire joined to a tungsten wire. Both are enclosed in a single ceramic capillary tube. Electrical connections can be made to the upper portion of the tungsten wire which extends outside the glass tube. The assembled electrode is filled with the desired amount of silver chloride and sodium chloride through the side arm of the glass T-tube. This portion is sealed off while the entire electrode is being evacuated.

Porcelain capsules of two compositions have been made, one containing 2.5 percent soda ( $\text{Na}_2\text{O}$ ) and the other 10 percent. Electrical measurements at different temperatures showed that the porcelain material containing 10 percent soda has the lower resistivity. The resistivities of both porcelains are many times lower than that of glass, the 10 percent  $\text{Na}_2\text{O}$  porcelain having only one-hundredth the resistivity of glass at equivalent temperatures. Conduction is entirely by movement of sodium ions.

A first step in preparing the porcelain materials is the formation of a glass by dry-milling a mixture of sodium silicate ( $\text{Na}_2\text{SiO}_3$ ), silica, and alumina and firing at 1100 C. The resulting glass is then milled with clays and water to produce a slip. The slip is formed into an electrode tube or capsule by casting in a mold of plaster of Paris. After drying, the porcelain capsule is fired at 1285 C.

The reproducibility and stability of the porcelain reference electrode were checked by measuring the potential of a cell in which identical electrodes were opposed. The results showed that the electromotive force of the electrodes was stable and reproducible to within a few millivolts under temperature cycling for almost six days. The fact that the electrode can be reused is an added advantage.

### Supplementary Information

Additional experiments were conducted to study variation in the electromotive force of the porcelain electrode. Two electrodes with different silver chloride and sodium chloride concentrations were placed in a cell and cycled at random between 646 and 850 C for several days. Repeated readings at the same temperature agreed within about 1 mv. The data indicated that the porcelain electrode behaves normally with respect to temperature change.

Another important property of an electrode is its ability to return to equilibrium after accidental passage of current.

To check this property, a cell was polarized by passing a 0.1-amp current through it for 20 seconds at 800 C. A polarization of 6 mv was measured immediately after applying the current. This decayed to about 1 mv within 5 minutes. Reversal of the polarizing current gave an equal but opposite polarization which decayed within 5 minutes to about 0.3 mv. Within 20 minutes, the residual polarization was less than 0.1 mv. The results showed that the porcelain electrode is highly reversible to passage of current.

Although the performance of the porcelain electrode may be improved with further study, the present work shows that the electrode is stable and reproducible. These characteristics make the porcelain electrode desirable for use in electrochemical studies of fused salt systems.

Additional details have been published in an article by R. J. Labrie and V. A. Lamb entitled "A Porcelain Reference Electrode Conductive to Sodium Ions for Use in Molten Salt Systems," which appeared in the October, 1959, Journal of the Electrochemistry Society.

## Electric Cars May Use Nickel-Cadmium Batteries

Research is being conducted on the feasibility of developing a modern version of the old electric car that faded from the American automobile scene because conventional batteries had such short lives.

A sintered plate, nickel-cadmium battery being studied is expected to last the life of the car and can be changed considerably quicker than other batteries.

Each cell of the new battery is made up of plates of carbonyl nickel powder sintered on a foundation of nickel wire mesh.

Biggest problem in developing the electric car is to find a method of extending the power plant's range but to keep the vehicle small and light. At present, batteries need recharging after less than 100 miles. To overcome this problem, American Motors and Sonotone Corp., Elmsford, N. Y., are exploring the feasibility of using a generator driven by a small auxiliary gasoline engine to recharge the battery during operation.

The electric car of tomorrow, as studies are being made, probably will be cheaper to operate than gasoline powered automobiles and probably will be practically trouble-free, eliminating costly service bills.

## Rapid Aluminum Welding

Ultrasonic seam welding of light gauge aluminum sheet and foil in thicknesses ranging from 0.006 to 0.010 inches at speeds in excess of 30 feet per minute has been developed by Aeroprojects, Inc., and Aluminum Company of America. The new welding process is expected to increase production and save money for container and packaging manufacturers, automobile radiator makers and the electrical industry.

In 1958, 210,300 copies of 12 NACE Technical Committee Reports were distributed.

## GOD BLESS 'EM

Our competitors do more for us than our friends. Our friends are too polite to point out our weaknesses, but our competitors go to great expense to tell of them.

Our competitors are efficient, diligent and attentive. They make us search for ways to improve our products and our services.

Our competitors would take our business from us if they could. This keeps us alert to hold onto what we have. If we had no competitors, we might become incompetent, inattentive, and possibly lazy.

We salute our competitors; they have been good to us. We need the discipline they enforce upon us.

God bless them all.

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## Plastic Engineers' Society To Meet January 12-15

The Society of Plastics Engineers' 16th Annual Technical Conference will be held January 12-15 at the Conrad Hilton Hotel in Chicago, Ill.

An advance program of the conference lists the following topics to be discussed:

January 12: polymer structure, physical properties, blow molding, fabricating and finishing, casting and plastics tooling, and plastics in buildings.

January 13: injection molding, extrusion, reinforced plastics, standards for reporting properties—thermosetting molding, plastics in electrical insulation, packaging, and vinyl plastics.

January 14: New materials, mold design, forming, foams, metals for plastics molds and plastics in the automotive industry.

January 15: industrial design—coloring, radiation and missiles and rheology.

Additional information can be obtained from the Society of Plastics Engineers, Inc., 65 Prospect St., Stamford, Conn.

## Maintenance Conference

"Working Against Air and Water Pollution" will be one of the many topics to be discussed at the 11th Plant Maintenance and Engineering Conference to be held at Convention Hall, Philadelphia, Pa., January 25-28.

Speaker on air pollution for this discussion topic will be William R. Bradley, American Cyanamid Company. R. W. Ladd of Delaware Refinery, Tidewater Oil Co., will speak on water pollution.

## Metal Deformation

A conference on the response of materials to high velocity deformation will be held July 11-12 in Estes Park, Colo., sponsored by the Physical Metallurgy Committee, Institute of Metals Division, the Metallurgical Society of AIME.

Papers to be presented will be on crystallographic, metallographic and basic metallurgical phenomena that occur in metals under high strain rate.

## New Flux for Aluminum

A new method makes it possible to solder aluminum without complicated tinning and fluxing operations. A glass fiber brush is rubbed through molten solder on the metal surfaces to be joined. The brush abrades the metal, removing oxide for a firm, smooth joint. The new system was developed by Reynolds Metals Co.

## Catalogs List Research

Two new catalogs listing research reports in the fields of cermets and rust prevention and removal have been published by the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

The catalogs are titled "CTR-319 Cermets, 1940-59" and "CTR-305 Rust Prevention and Removal, 1934-59." The price is 10 cents each.

Over 20,000 cards have been issued by the NACE Abstract Punch Card Service.

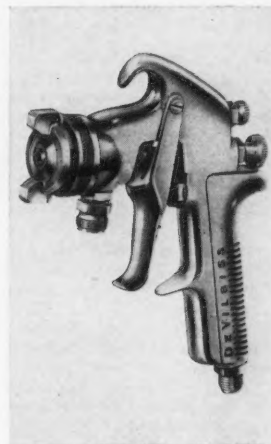
# Proper application is half the battle!

**You can't fight corrosion effectively with hit-or-miss methods . . . however good your material. You need full coverage of every crevice, recess, and sharp edge . . . and the only practical way is with non-contact application methods. Here's how:**

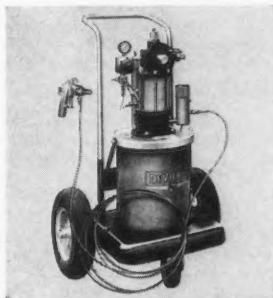
**Conventional spray eliminates thin edges . . .** gives full-covering film build where it's needed most—on ridges, corners, projections subject to greatest wear and exposure. Methods that wipe, brush, or roll material onto surface by contact often leave these critical points with the least coverage.

**Hot spray gives heavier film build . . .** assures uniform viscosity of material . . . permits application of higher solid-content materials . . . reduces shrinkage that draws film thin over sharp corners during drying. Cuts down overspray, reduces pinholing. Permits painting when temperature is too low for conventional application.

**Airless spray speeds painting of big areas . . .** lays on full coats fast and with minimum spray fog. Sprays even heavy materials without the use of atomizing air.



Conventional spray equipment



Airless spray equipment



Catalyst spray equipment

If you have a corrosion problem that coating can solve—call on DeVilbiss. We offer the industry's most complete line of spray equipment—including catalyst guns for applying such new materials as flake fiberglass, and for laboratory or experimental use in applying foam-in-place urethane foams and other plural component materials.

For details—call your DeVilbiss representative, or write us direct. We'd like to help you explore the many advantages of modern methods of application for all of today's coating materials. Our technical experience and research facilities are yours to draw on. *The DeVilbiss Company, Toledo 1, Ohio.*

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Toledo 1, Ohio - Barrie, Ontario - London, England  
Sao Paulo, Brazil  
Branch Offices in Principal Cities

## Equipment Services

# NEW PRODUCTS

## Materials Literature

### Aluminum

**Killark Electric Mfg. Co.**, Vandeventer and Easton Aves., St. Louis, Mo., manufactures an aluminum fitting for concrete mounting that is claimed to be explosion proof. The new fitting, Series GRC, is available with blank cover for use as a splice box and hub cover suitable for fixture hanging. The fitting is available in conduit sizes from one-half inch to one inch in a variety of hub styles.

### Boilers

**Water Service Laboratories, Inc.**, 615 W. 131st St., New York 27, N. Y., have published (Technical Bulletin No. 597) on priming and foaming in low pressure heating boilers.

**Water Control System** for side-stream boiler that automatically eliminates sludge and suspended solids has been introduced by the Sparkler-Filtrion Corp., North Chicago, Ill. The unit combines continuous sidestream filtration with chemical pretreatment, internal treatment, continuous minimum blowdown, feedwater preheating and degassing in one automated unit. Scaling, corrosion and caustic embrittlement are reduced, according to the manufacturer.

### Catalogs

**Simplified Catalog Sheet** covering spray guns for die lubrication is available from DeVilbiss Company, Toledo, Ohio. Included are automatic guns for applying lubricating oils or drawing compounds to dies and for applying coolants to abrasive wheel and belts.

**New Chemicals Catalog** is available from Dow Chemical Co., Midland, Mich., which describes properties and uses of 375 industrial pharmaceutical and agricultural chemicals produced by the company. Catalog includes an expanded section on plastics and coatings products.

**Platinum Products Catalog** including standard line of platinum products, chemicals, recovery and refining facilities of the company is available from J. Bishop & Co., Platinum Works, Malvern, Pa. Information on clads and composites of platinum group metals with base metals is included.

### Cleaning

**Hydraulic Jet Cleaners** for plant and tank cleaning are described in two bulletins published by Sellers Injector Corp., 1600 Hamilton St., Philadelphia 30, Pa. Bulletin No. 442 describes high pressure and low pressure jet cleaners and sandblast and chemical cleaning equipment are described. Bulletin 432 describes a special head with high velocity nozzles. The head rotates the nozzles in both vertical and horizontal planes for cleaning the inside of tanks.

**Solvent Cleaning Functions** of the Dow Chemical Company will be handled under a newly created division of the company. The division also will pro-

vide services and products in the municipal and industrial waste and water treatment fields. Headquarters will be in Cleveland.

**Blast Cleaning**, metal abrasives and dust control equipment produced by Pangborn Corp., Hagerstown, Md., will be marketed in Canada by Pangborn Canada, Ltd. Offices will be at 38 Mattson Rd., Toronto, Ont.

### Coatings—Inorganic

**Totrust Flash-Dry M-50 Primer** recently introduced by Wilbur & Williams Co., Inc., 650 Pleasant Street, Norwood, Mass., dries in 15 minutes and penetrates rust pits and other surface irregularities to form a bond with the metal surface, according to the company. Rust inhibition of the coating is provided by National Lead Company's M-50 (Basic Lead Silico Chromate) pigment.

### Coatings—Organic

**Wyandotte Chemicals Corp.**, has developed a new sprayed rigid polyether-based urethane foam for use in corrosion control and as insulation. New techniques and spraying equipment developed by the DeVilbiss Co., Toledo, Ohio, have been designed to reduce cost of equipment needed to apply the foam. Insulating and corrosion protective qualities indicate use of the product as exterior coating for tanks, pipes and pipe lines.

**Dylex KCD-141**, a new latex with low foaming advantages for use in metal primers has been announced by the Plastics Division of Koppers Co., Inc., 801 Koppers Bldg., Pittsburgh 19, Pa. Company salt spray tests indicated excellent corrosion resistance, it was claimed. Company bulletin C-9-282 describes the product.

**Centrifugal Casting Method** is being used to apply coal-tar pipe line enamel to 57 sections of steel pipe, 13 feet in diameter. The enamel, made by Koppers Co., Inc., is applied by insertion of a long wire in the pipe after the pipe has attained a peripheral speed of 900 feet per minute. Hill-Hubbell Company, 3091 Mayfield Drive, Cleveland 18, Ohio, is applicator of the coating. The pipe will carry 50,000,000 gallons of water per hour for an electric generating station.

**Aroplaz 6006** is a new top coating which sets tack free in about five minutes and hardens into a tough, glossy finish without baking, according to the manufacturers, Archer-Daniels-Midland Co., 700 Investors Bldg., Minneapolis 2, Minn. The new resin is a pure oxidizing oil modified alkyd, the firm states. Possible uses are for finish coatings of farm and construction machinery, trucks and trailers, metal cabinets and as a repainting coat for autos.

**Rez-N-Lac**, made by the Schwartz Chemical Co., Inc., 50-01 Second St., Long Island City 1, N. Y., is a new coating formulation developed for fast

application and durable colors for products made of high impact styrene material.

**Del Products**, made by David E. Long Corp., 220 East 42nd St., New York 17, N. Y., are described in Bulletin 105 published by the company. The bulletin states Del synthetic rubber compound is waterproof and non-shrinking, has resilience over a wide temperature range, adheres to most materials, is easily applied and is inert to weathering and most corrosives. A chemical resistance chart is printed as a general guide in selecting the most suitable formulation.

**Farboil Company**, Baltimore 30, Md., is marketing a new system of protective coatings for the building, industrial and marine fields, called Farboil Epoxthanes. The paints are said to be resistant to corrosion, abrasion, solvents, impact and chemical attack. They are flexible yet cure to 75 percent the hardness of glass and will adhere to glass, metal, concrete and wood, according to the manufacturer.

**Prufcoat Primastic**, a protective coating which is said to combine rust-inhibitive primer properties with the chemical resistance of a catalyzed epoxy coating, has been developed by Prufcoat Laboratories, Inc., Cambridge, Mass.

### Chemicals

**Manning & Lewis Engineering Co.**, 30 Ogden St., Newark, N. J., has published an 8-page catalog which describes the company's line of chemical process and heat exchange equipment.

### Cooling Towers

**Water Service Laboratories, Inc.**, 615 W. 131st St., New York 27, N. Y., have published suggestions on winter operation of outdoor cooling towers. The leaflet is designated Technical Bulletin # 598. The firm specializes in chemical engineering and corrosion prevention services.

**Joy Manufacturing Co.**, 1201 Macklind Ave., St. Louis 10, Mo., has made their "Safe" switch in a 6-station model for pendant applications. The entire switch including buttons is enclosed in a non-corrosive, waterproof molded synthetic rubber housing which is light in weight.

### Heat Exchangers

**Parallel Exchanger**, an impervious graphite heat exchanger for limited volume heating or cooling requirements in handling corrosives, is being made by Falls Industries, Inc., Aurora Road, Solon, Ohio. Both heating and cooling passages are drilled parallel to each other in the exchanger.

### Heat Treatment

**Heat Treatment** to relieve stresses in thermostat metal parts is described in a leaflet available from General Plate Products Group, Metals and Controls Division, Texas Instruments, Inc., 34 Forest St., Attleboro, Mass.

(Continued on Page 86)





## Cut Maintenance and Replacement Costs with **TAPECOAT**<sup>®</sup>

**... the Coal Tar Tape Coating  
that Adds Years of Service Life  
to Gas Lines**

No wonder more and more distribution engineers are selecting TAPECOAT products as an important part of their program in fighting underground corrosion! Experience shows that quality protection applied during installation prevents huge maintenance and replacement expense at later dates.

Since 1941 when TAPECOAT originated coal tar coating in tape form, it has proved to be the best protection money can buy for combatting corrosion underground or under water. Lines in service TAPECOATED as far back as 17 years ago show no signs of deterioration—a record of uninterrupted service no other type of tape can match.

TAPECOAT comes in rolls of 2", 3", 4", 6", 18" and 24" widths—sized to the job for protecting pipe, pipe joints, couplings, fittings, tanks, conduit, cable and tie rods. TAPECOAT is both bond and protection in one—easy to apply with the flash of a torch.

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When primer is specified, use TC Prime-coat, the compatible coal tar primer.



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Representatives in Principal Cities

Manufactured and distributed in Canada by The Tapecoat Co. of Canada, Ltd., 25 Haas Road, Rexdale, Ontario

## NEW PRODUCTS

(Continued From Page 84)

### Heaters

**Industrial Radiant Heater** engineered for quick warm-up and cool-off has been developed by Corning Glass Works, Corning, N. Y., for drying, baking, curing and pre-heating. The tubular unit reaches heating capacity of 800 to 850 F within three minutes, according to the manufacturer.

### Inhibitors

**O'B-Hibit-L 32**, a liquid corrosion inhibitor designed for use with muriatic acid, phosphoric and other liquid acids, has been developed by O'Brien Industries, Inc., P. O. Box 72, Caldwell, N. J. Recommended concentration is from 2 to 3 percent by volume with the concentrated acid.

**CRC 2-26**, a liquid inhibitor designed to displace and seal out moisture and protect against caustic and acid fumes, is described in an illustrated folder published by Corrosion Reaction Consultants, 116 Chestnut St., Philadelphia 6, Pa. The product has special application in drying out flooded or damp motors and protecting electrical equipment. With one-third the surface tension of water and a high capillary action, CRC 2-26 forms a continuous molecular film that penetrates grain boundaries in metals and penetrates into crevices, makers say.

### Instruments

**Hazegage Combustion Indicators** provide continuous and instant information for maintaining optimum combustion. They are made by Photomation, Inc., 90 S. Washington Ave., Bergenfield, N. J. The instrument uses photoelectric cells. Direct reading and recording indicators are available and a panel of red and green lights indicate whether combustion conditions are satisfactory.

**Long-Life Ionization Gauge** using a thorium-coated iridium filament is described by NRC Equipment Corp., 160 Charlemont St., Newton 61, Mass., in a recent bulletin. The gauge, Model 527, is burn-out resistant, having been subjected with current on to as many as 175 bursts from 1 micron to atmospheric pressure before failure, manufacturers state. Uses expected for the instrument are in vacuum metallizing, vacuum melting and heat treating, space simulation and laboratory investigations.

### Insulators

**Coustifab**, a lead containing material for noise abatement in piston engine and jet engine aircraft and other uses, is a lead powder impregnated vinyl coated cotton duck or woven glass fabric. Cordo Chemical Corp., Norwalk, Conn., developed the product.

**Universal Insulating Meter Nuts** of special size and design are available from Universal Controls Corp., Dallas, Texas, for use on Sprague No. 1A and No. 2 combination meters and regulators. Previous nuts interfered with the regulator spring case or cover of the combination meter.

### Lubricants

**Dag 207**, a newly formulated lubricant for high temperature use is described in a leaflet from Acheson Colloids Co., Port Huron, Mich. The lubricant is described as a concentrated dispersion of colloidal molybdenum disulfide in an LB series, fluorocarbon lubricant. Typical uses are for oven conveyors, kiln cars, gears and bearings and for glass making machinery.

### Metals—Ferrous

**Republic 50** high strength steel used instead of carbon steel increases payload and combats corrosion on refuse hauling trucks, according to Republic Steel Co., 500 Fifth Ave., New York 36, N. Y. Use of a two-ton chassis instead of a three or three-and-one-half truck chassis is made possible by specifying Republic 50, the firm states.

**Carpenter Steel Co.**, 372 West Bern Street, Reading, Pa., has published a 40-page guide for buyers of specialty steels. It contains detailed information on tool and die steels; stainless steels; high temperature alloys; electronic, magnetic and electrical alloys; special purpose alloy steels; tubing and pipe; and fine wire specialties. A tool steel selector chart which provides a system of matching tool steels is also included.

**Potomac A High Strength Steel** for use in aircraft, missiles and rockets is described in a booklet available from Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pa. Known as type H-11, the steel has high strength up to 1000 F.

### Metals—Non-Ferrous

**Ampcoloy 666**, a new extruded manganese-bronze alloy for high production jobs, is described in a data sheet available from Ampco Metal, Inc., 1745 South 38th St., Milwaukee 46, Wis. Included are chemical composition, physical properties, resistance to wear and corrosion and advantages of the new alloy.

**New Corrosion Resistant Alloys** have been developed by Stainless Foundry & Engineering, Inc., 5132 North 35th St., Milwaukee 9, Wis., for handling sulfuric acid. Illium 98, improvement in the original Illium G formula, handles 98 percent sulfuric acid up to 110 C and resists all concentrations up to 90 C, the firm states. Illium B in hardness grades of 200 to 360 Brinell is used in wear, bearing or cutting applications where corrosion is a major problem, the company claims.

### Minerals

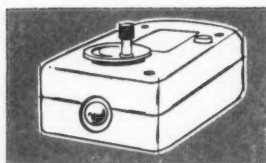
**Lithium Metal** technical data is published in Bulletin 101 by Foote Mineral Co., 18 W. Chelton Ave., Philadelphia 44, Pa. Suggested uses of the metal are given. Its physical and chemical properties as an element, combined with other elements or alloys are given.

### New Plants

**Cardox Division, Chemetron Corp.**, Chicago, Ill., is constructing a plant near Philadelphia, Pa., to recover carbon dioxide from ammonia. Production will be about 155 tons of liquid and solid carbon dioxide a day.

(Continued on Page 88)

## NEW POCKET SIZE SINGLE-PROBE THICKNESS GAUGE



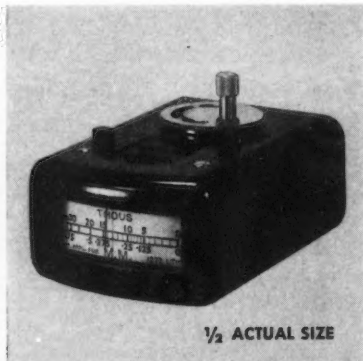
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THREE SCALES	
M.894A	0 — .030"
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M.894C	0 — .005"

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MORE RUGGED

Single-probe assures accurate measurements on either flat or curved surfaces. Measures thickness of paint, enamel, lacquer, plastic or any non-ferrous metal coatings without damage to coating. Pointer clamp locks needle for readings on out-of-the-way spots. Gives reading in both inches and millimeters. Complete with durable leather case which fits on belt.

# Mn

## new specialty Wrought Iron offers better low temperature properties and better impact resistance than many steels

Mn (Manganese) Wrought Iron is a brand new specialty wrought iron offering excellent impact resistance at sub-zero temperatures. To define it: Mn Wrought Iron is a highly deoxidized, low carbon alloy wrought iron containing 1% manganese.

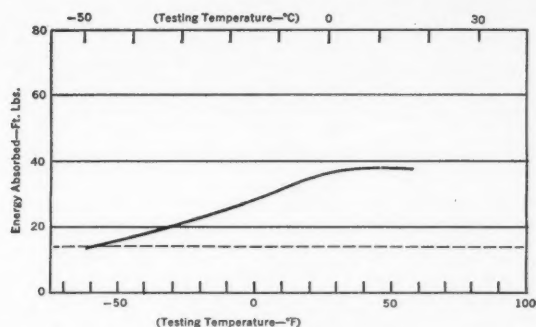
New Mn Wrought Iron is not a substitute for 4-D Wrought Iron. Mn was developed *specifically* to meet critical engineering needs for a tough, yet economical metal in low temperature services where the possibility of brittle failure poses design problems.

Independent impact testing of Charpy V-notch specimens from ½" plate shows that Mn Wrought Iron has a mean energy absorption of 15 foot-pounds at -58°F. Mn Wrought Iron combines this boost in impact strength with the excellent corrosion resistance and mechanical advantages of 4-D Wrought Iron. Mn can be easily welded or flame cut—in field or shop—without requiring pre-heating or post-heating treatment.

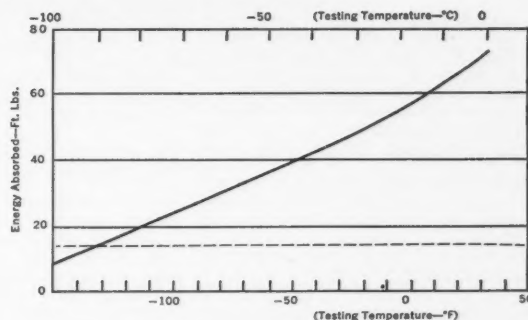
Mn Wrought Iron costs *less* initially than many of the low alloy steels recommended for low temperature service. Available in pipe, plate, and other forms, this new material is well suited for a wide variety of low temperature applications, including such services as tanks and process piping in the refrigeration and petrochemical industries.

Inquiries regarding this specialty wrought iron will receive immediate attention. Write: A. M. Byers Company, Clark Building, Pittsburgh 22, Pennsylvania.

### Charpy impact values for Charpy V-notch specimens machined from conventionally-produced ½" Mn Wrought Iron plate in as-rolled condition.



Mean energy absorption: 15 ft-lbs at -58°F, notch perpendicular.



Mean energy absorption: 15 ft-lbs at -125°F, notch parallel.



### BYERS WROUGHT IRON

TUBULAR AND FLAT ROLLED PRODUCTS



## NEW PRODUCTS

(Continued From Page 86)

### Non-Metallics

**Karbate**, an impervious graphite, is being used for a valve and modular entrainment separator manufactured by National Carbon Company, division of Union Carbide Corporation.

### Pipelines

**Perrault Supply Co.**, a division of Allied Paint Mfg. Co., Tulsa, has been formed to specialize in materials used to stem pipeline corrosion. V. V. Malcolm is general manager of the new division; Ainslee Perrault is president of Allied Paint. The firm will handle pipeline felt, rock shield, glass pipe wrap, internal coatings and other materials. Malcolm, formerly vice-president and general manager of Perrault Equipment Co. until its recent sale by W. O. Dixon to M. J. Crose Mfg. Co., has had many years of experience in the pipeline protection business. Ainslee Perrault, was one of the founders of Perrault, Inc., a pioneer firm in the pipeline field. Eastern and export representative for Perrault Supply Co. is Andreason-Lundberg Corp., 45 Rockefeller Plaza, N. Y.

### Piping

**Recommended Piping Practice**, a wall chart available from Lunkenheimer Co., Beekman, Waverly and Tremont Streets, Cincinnati 14, Ohio, describes basic valve types, end connections normally used, installation and maintenance tools, installation and operation and maintenance.

**New Unitrace Fittings** for piping with integral steam tracing have been developed by Alcoa. Designed to incorporate Unitrace into standard piping systems, fittings include a flange, adapter flange and 90-degree elbow. A descriptive booklet is available from Aluminum Company of America, 778 Alcoa Bldg., Pittsburgh, Pa.

### Plastics

**Schwartz Chemical Co., Inc.**, 50-01 Second St., Long Island City 1, N. Y., is making a new acetate cement with a flash point above 100 F to reduce mass production hazards in the bonding of cellulose acetate or butyrate sections. It will not thicken when applied from open containers, but viscosity can be increased for special applications by adding cellulose acetate shavings, according to the company.

**Estane VC**, a plastic film strong enough to be made into flexible gas tanks for automobiles or rugged rainwear, has been developed by B. F. Goodrich Industrial Products Co., Akron, Ohio, the company states. The thin but tough material retains its strength even when stitched. It can be sealed to itself electronically or by a heat seal to form a leakproof cell.

**Flange Insulation Sets** made of high density polyethylene tubing are being marketed by Central Plastics Distributing Co., P. O. Box 762, Shawnee, Okla. Full length sleeves, fabric reinforced phenolic washers and steel washers, along with one-eighth-inch phenolic, neoprene faced phenolic or Johns-Manville style 71 asbestos center gaskets are made by the firm which specializes in corrosion control products.

### Research

**Taylor Fibre Co.**, Philadelphia, Pa., has organized an advanced materials division to investigate and develop laminated plastics and vulcanized fibre for use in rockets, missiles, jet aircraft, nuclear reactors and other products where high strength-to-weight ratio, excellent heat insulation and electrical insulation are important factors.

### Rubber

**New Type of Viton**, synthetic rubber, has doubled the product's useful life at temperatures from 500 to 600 degrees F and in certain strong chemicals. E. I. du Pont de Nemours & Co., Wilmington, Del., states. Tests at 500 to 600 F showed elasticity of the product was retained twice as long as the former product.

### Soldering

**New Liquid Flux** for use with all soft solders has been developed by the research department of All-State Welding Alloys Co., Inc., White Plains, N. Y. It can be used on most metals, including stainless steel, gold and galvanized metals, except aluminum, magnesium and die cast metals, according to the manufacturer.

### Valves

**Foot Valve Made by Chemtrol**, 10872 Stanford Ave., Lynwood, Cal., of all-molded plastic construction is designed to be used in sumps, tanks and other uses where fluid level must be reduced or fluid completely withdrawn. The valve is practically inert to corrosive influences, makers state. The ball-type check valve prevents back flow, and the suction end is protected against debris intake with a large hemispherical plastic screen.

**Delsen Corp.**, 719 W. Broadway, Glendale 4, Cal., has developed an air operated, solenoid controlled valve available for use with the firm's automatic weighing scale, the Autogram. The equipment is designed for weighing and dispensing batches of one or several liquids.

**Whittaker Controls**, 915 North Citrus Ave., Los Angeles 38, Cal., has developed new gate valves with mechanically loaded and retained plastic seals, roller type clutches and interchangeability of actuators. The valves will be made in quantity, then adapted to meet requirements, rather than being built individually to special specifications.

### Water Softeners

**Zeotone**, made by the Calgon Company, P. O. Box 1346, Pittsburgh 30, Pa., has been developed to clean and improve the zeolite or resin bed in commercial or industrial water softeners. It is said to be effective for cleaning all softeners regenerated with salt, on resinous exchange material and on synthetic and natural zeolites.

### Welding

**Arcair's Model H-55** torch has a push button air control valve in the torch handle which provides air on both sides of the electrode. Made by the Arcair Co., P. O. Box 431, Lancaster, Ohio, the torch has primary uses in foundries for flash removal, cutting holes or similar jobs which require frequent reversal of travel direction.

## POSITIONS WANTED AND AVAILABLE

Active and Junior NACE members and companies seeking salaried employees may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point type. Advertisements to other specifications will be charged for at \$10 a column inch.

### Positions Available

**Sales Engineer.** New corrosion resistant plastic tank is being added to old complete corrosion service line. Will require extensive travel in south and southeast. An automobile will be furnished. Commission on sales will be added to base salary. Include complete personal and experience resume. Stetsco Service Co., P. O. Box 3213, Charlotte 3, N. C.

**Cathodic Protection Engineer**—Good opportunity in sales engineering. Experience in cathodic protection work required. Midwest location with travel. Good salary. Growing company. Send resume of experience, photo. Corrosion Services, Inc., Box 787, Sand Springs, Okla.

### Manufacturers' Agents

**Manufacturer of Materials** for pipeline protection presently expanding sales force into Northeastern Region, offers permanent, life-time franchises

to sales agents contacting pipeline, public utility, refining and chemical industries. New England, North Jersey, Philadelphia, Baltimore, Pittsburgh and Cleveland areas. CORROSION, Box 59-43.

### Positions Wanted

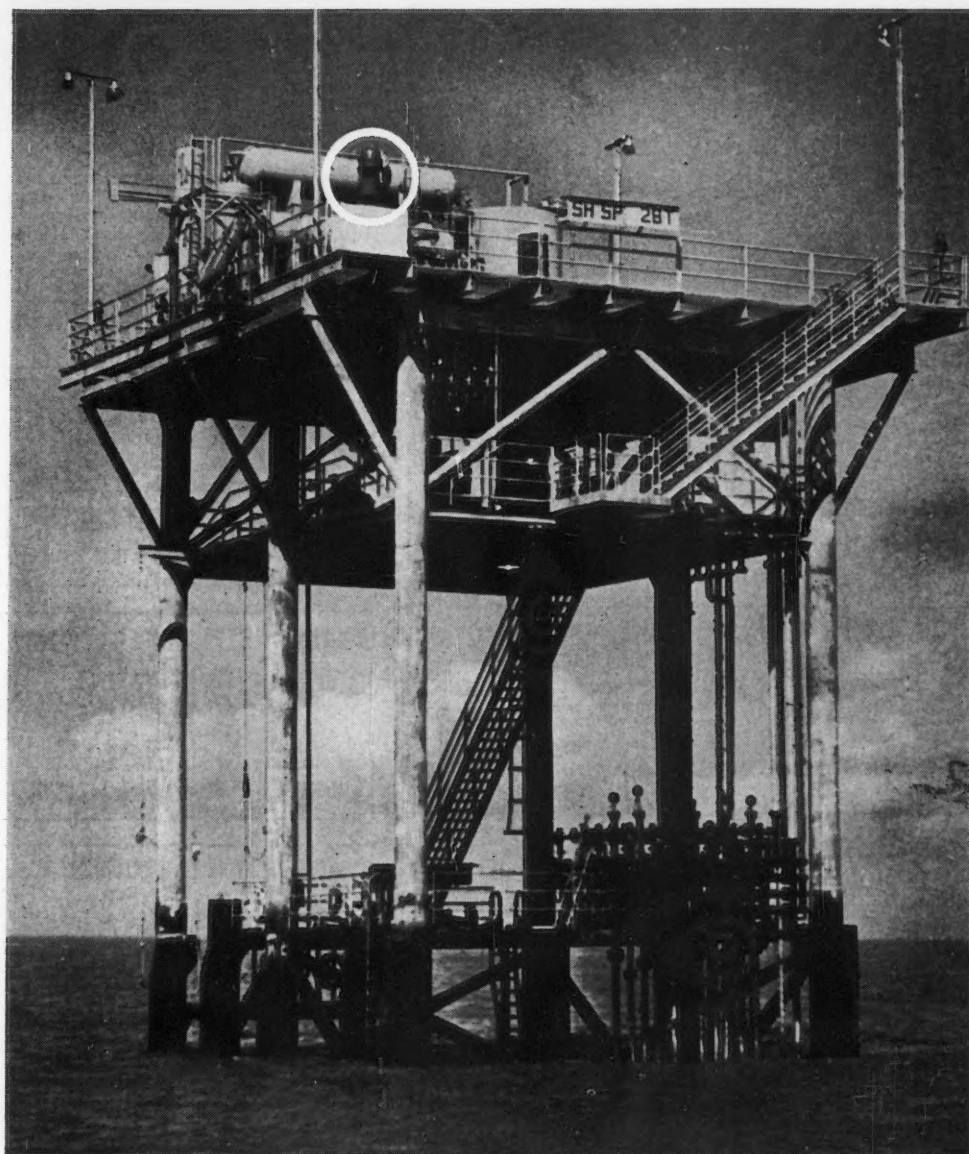
**Sales Engineer.** 12 years experience—sales, management, engineering—in industrial and municipal water and waste treatment and corrosion control. Prefer Middle Atlantic states. Will consider representation. CORROSION, Box 59-41.

**Corrosion-Metallurgical-Equipment Inspection Engineer.** Seven years corrosion, metallurgy, equipment and welding inspection major refining, petrochemical plants. Supervisory experience. BS Met. E. Age 30. \$10,000 present salary. Prefer Southwest, South. Other areas considered. CORROSION, Box 59-42.

**Technical Representative**—Age 33, 4 years in research including organic inhibitors. Field experience in coatings and cathodic protection of production equipment. Prefer growing aggressive firm in southwest. Resumé on request. CORROSION, Box 59-45.

CYANAMID

## CORROSIONEERING WITH REINFORCED LAMINAC® PLASTIC



Winner of an Award of Merit for design excellence at the 14th Annual Exhibit and Conference of the Reinforced Plastics Division, The Society of the Plastics Industry, Inc.

Four ft. tall and 17½ in. in diameter, the horn is produced by Wallace & Tiernan Inc., Belleville, N. J.

## CAREFREE SENTINEL ON THE GULF OF MEXICO

The man-made oil drilling islands at the mouth of the Mississippi are under continuous corrosive attack by harsh marine atmospheres. So equipment must be made *impervious* to corrosion. The foghorn, for instance, that warns shipping of the presence of islands, like this Shell Oil Company, Delta Division, oil-drilling rig, is fabricated of rugged glass-reinforced LAMINAC® polyester resin. The reinforced LAMINAC foghorn is completely *corrosion resistant*, as well as resistant to impact. Weighing just 120 pounds, it can be lifted by one man. The previous metal horn required a crane to move it. *And the reinforced plastic horn requires no maintenance.*

CYANAMID

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Dallas • Detroit • Los Angeles • Minneapolis • New York • Oakland  
Philadelphia • St. Louis • Seattle

In Canada: Cyanamid of Canada Limited, Montreal and Toronto

## MEN in the NEWS

V. V. Malcolm is general manager of Perrault Supply Co., a division of Allied Paint Mfg. Co., Tulsa formed to operate in the pipeline corrosion protection field. He formerly was vice-president and general manager of Perrault Equipment Co., an engineer and manager for Philip Carey Mfg. Co., Cincinnati and has had long experience in the pipeline protection business.

Frank Donat has joined the chemicals and plastics research department at B. F. Goodrich Company's Research Center, Brecksville, Ohio.

Walter H. Flynn has been appointed general sales manager for Lebanon Steel Foundry, Lebanon, Pa.

F. H. Foglesong has been named to the newly created position of manager of alloy sales for Babcock & Wilcox Company's Tubular Products Division, 161 E. 42nd St., New York, N. Y.

Cooper F. Hawthorne, NACE member, has been appointed vice president and general manager of the newly organized Metal Services Inc., Beaumont, Texas.

Henry H. Hemenway has been appointed director of research and engineering for Graver Tank & Mfg. Co., 4809 Tod Ave., East Chicago, Ind.

Lafayette K. Irwin has been appointed chief of the engineering mechanics section of the National Bureau of Standards, Washington 25, D. C.

Earl L. Jolly, NACE member, has been appointed Pacific-Western area manager

for the new Corr-Prev Division of Chase & Sons, Inc., at San Francisco.

Charlotte Kraebel has joined the chemical and plastics research department at B. F. Goodrich Company's Research Center, Brecksville, Ohio.

Alexander S. Zelle, NACE member, has been appointed chief engineer of Bridgeport Rolling Mills Company, P. O. Box 818, Bridgeport, Conn.

Thomas W. Morrison has been appointed director of engineering and research for SKF Industries, Inc., Front Street and Erie Ave., Philadelphia 32, Pa.

George K. Nelson has been named manager of Archer-Daniels-Midland Company's chemical products division, 700 Investors Bldg., Minneapolis 2, Minn.

William F. Newbold has been appointed

## CORROSION ENGINEERING DIRECTORY

**WAYNE BROYLES**  
ENGINEERING CORP.

CATHODIC PROTECTION  
Installation  
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Plans • Specifications  
Electrolysis Control  
Testing

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**SOUTH FLORIDA TEST SERVICE**  
INCORPORATED

Testing—Inspection—Research—  
Engineers

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director of research for Brown Instruments Division of Minneapolis-Honeywell Regulator Co., Wayne and Windrim Avenues, Philadelphia 44, Pa.

**Royce A. Peabody** has joined the technical sales and service staff of Resistoflex Corporation, Roseland, N. J.

**C. W. Powell** has been appointed southern district manager for metallurgical products department of General Electric Company in Atlanta, Ga.

**Richard F. Protiva** has been appointed market development manager of Heil Process Equipment Corp., Cleveland, Ohio. **Robert E. Scheel** was named manager of national branch sales.

**William A. Wood, Jr.**, NACE member, has joined the technical sales staff of Carboline Co., P. O. Box 14284, Houston, Texas.

**Hartley J. Davis**, NACE member, is now eastern division manager of Corrosion Services Inc. His offices will be at 1309 Washington Ave., Cleveland 13, Ohio.

**K. A. Phillips**, NACE member, has been appointed director of research and development at American Zinc, Lead & Smelting Co., P. O. Box 495, East St. Louis, Ill.

**Wilfrid G. Matheson**, supervisor of incandescent lamp research for Sylvania Lighting Products, has been named president of the American Vacuum Society.

**Walter A. Steiner** has been appointed vice president of technology for National Carbon Company, division of Union Carbide Corp., 30 East 42nd St., New York 17, N. Y.

**Douglas E. Rood**, NACE member, has joined the Corr-Prev division of Chase & Sons, Inc., as manager of the company's southwest area. His office will be in Houston, Texas.

**G. W. Rupp**, president of Inertol Co., Inc., 480 Frelinghuysen Ave., Newark 12, N. J., is celebrating his 25th year with the company.

**Robert E. Siegfried**, NACE member, has been appointed assistant engineering manager for Badger Manufacturing Co., Cambridge, Mass. **Philip H. Seaver** has been appointed manager of engineering sales.

**Louis E. Trapasso** has joined the chemicals and plastics research department of the B. F. Goodrich Company Research Center, Brecksville, Ohio.

**Bruce L. Wilson** has been appointed chief of the mechanics division of the National Bureau of Standards, U. S. Department of Commerce, Washington 25, D. C.

**Donald S. Arnold** has been named manager of research at American Potash & Chemical Corporation's main plant at Trona, Cal.

**K. F. Egan** is sales representative in the New York district for Wolverine Tube, division of Calumet & Hecla, Inc. His offices will be Room 956, Sibley Tower Bldg., Rochester, N. Y.

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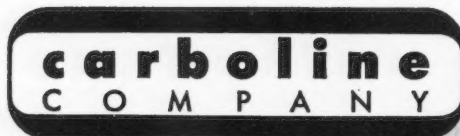
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# TECHNICAL TOPICS

## Characteristic Properties of

# Polyurethane Protective Coatings\*

**POLYURETHANE COATINGS** are one of the latest synthetic coating materials developed for protection of metals from corrosion. Urethane chemistry opens up a new field of reactions which have scarcely been examined in their practical applications. The isocyanates, which are the primary building blocks of the urethane system, are capable of reacting with many materials being used for coatings and thus creating new classes of materials.

Two articles concerning urethanes have been published in CORROSION. One described the chemical structure and characteristics of polyurethane coatings.<sup>1</sup> The other presented some new formulations that have been developed.<sup>2</sup>

### Preparation of Urethane Coatings

There are two main types of urethane coatings, distinguished by the method of packaging: in one or two-component systems.

The one-component systems are similar in handling to orthodox paints; the material may be sprayed or brushed on the surface to be coated and allowed to air-dry in the normal manner. The two-component systems are supplied in two separate packages which must be blended just before application and after blending the mixture must be used within a specified time. A rise of viscosity of the mixture usually takes place after blending. After the pot-life has expired, the material generally sets to an irreversible gel. Two-component systems are already familiar systems, the epoxies being the most familiar example.

The most durable water-resistant and chemical-resistant coatings have been formed only from the two-component systems. This article deals with the two-component systems.

Preparation of a two-component urethane coating is a straightforward procedure. The first container of such a system contains a polyester resin dissolved in suitable solvents. Pigments also are incorporated in this solution when required to provide hiding power and decorative value and to supplement the mechanical and physical properties of the film.

The second component consists of an isocyanate resin also dissolved in dry

solvent. When the two components are blended just before use, the isocyanate reacts with the free hydroxyl groups of the polyester resin to form the urethane. This reaction is not completed immediately; thus the mixture remains fluid for at least one day's work life. The reaction proceeds slowly throughout the curing period of the applied film, which lasts from a few hours to several days after application, depending on the type and quantity of the reactants.

For optimum performance, the reaction is allowed to proceed as long as possible under normal curing conditions before subjecting the coating to any destructive exposure. However, urethane coatings develop a very high proportion of their ultimate resistance properties after only one day's drying. Urethane films normally dry hard within three to eight hours after application, depending upon formulation, temperature and relative humidity.

Ultimate coating properties can be readily varied by choice of the polyester and change of the proportion of isocyanate resin to polyester resin.

Since the isocyanate is the more expensive of the two, a standard minimum ratio serves for the majority of uses. The ratio is 10 percent of the isocyanate resin above the stoichiometric equivalent of the two resins. Variation of properties is consequently more economically and conveniently achieved by varying the type polyester from highly branched types giving rigid films of maximum chemical resistance to linear polyesters which possess excellent flexibility, abrasion and water resistance but diminished chemical resistance.

Table 1 gives data on some physical properties of six typical urethane coatings and some familiar coatings.

Table 1 shows that the urethane coatings M-1 through M-5 are all extremely

### Abstract

Discusses the characteristic properties of polyurethane coatings. Gives description of the two-component system. Explains and presents data from chemical and solvent resistance tests, spot tests and other laboratory research. 5.4.5

hard yet show a wide range of flexibility as measured by the impact test. The abrasion loss of the urethanes is the lowest of all the materials tested despite variations of the flexibility.

### Chemical and Solvent Resistance Tests

Chemical and solvent resistance of urethane coatings have been evaluated in a number of distinct tests. The tests can be grouped under several different categories which differ mainly in length of time necessary to obtain comparative evaluations.

One method of testing is to prepare free films and suspend these in the liquid reagents. However, free films are difficult to prepare and present handling problems. A similar result is achieved by dipping small glass test tubes into the test coatings and allowing them to cure thoroughly. These can then be partially immersed in the test liquids in bottles. Several coatings may be tested together in the same bottle by this method.

Table 2 gives results on three urethane coatings compared with two commercial epoxy systems and a commercial vinyl. The glass probes were coated to give films approximately one mil thick within as close limits as were practicable by adjusting the viscosity and solids of the coating solutions.

Table 2 shows the number of hours at which the coatings on the probes failed after immersion in the test solution. Failure was observed by the film's

(Continued on Page 94)

TABLE 1—Typical Physical Data for Corrosion Resistant Coatings

Coating Type	Hardness <sup>1</sup>	Abrasion <sup>2</sup>	Impact <sup>3</sup>	No. of Components	Remarks
Urethane M-1.....	68	61	4	2	Highest chemical resistance
M-2.....	68	63	60	2	Chemically resistant
M-4.....	68	54	>160	2	Excellent water resistance
M-5.....	48	60	>160	2	Excellent water resistance and flexibility
One-component Urethane	6	137	90	1	Moderate resistance, low cost
One-component Urethane	10	139	4	1	Moderate resistance and cost
Chlorinated Rubber.....	12	200	10	1	Chemically resistant
Epoxy.....	22	120	50	2	Chemically resistant
Vinyl.....	6	75	120	1	Chemically resistant

<sup>1</sup> Sward, Glass = 100

<sup>2</sup> Taber, mg. loss per 1,000 cycles

<sup>3</sup> Reverse, inch-pounds

\* Revision of a paper titled "Polyurethane Protective Coatings—Properties and Applications" by E. R. Wells, Mobay Chemical Co., New Martinsville, W. Va., presented at a meeting of the Northeast Region Conference, National Association of Corrosion Engineers, Oct. 6-8, 1958, Boston, Massachusetts, and at a meeting of the Detroit Section, National Association of Corrosion Engineers, Oct. 16, 1958, Detroit, Michigan.



TABLE 2—Chemical Resistance of Coatings Tested by Glass Probe Method

Exposure	Coating Type					
	M-1	M-4	E-1	E-2	V	U-oil
<b>Mineral Acids</b>						
Hydrochloric (10%)	> 7300	20	20	3	50	20
Phosphoric (20%)	> 7300	4000	20	3	50	20
Sulphuric (30%)	> 7300	140	3	3	> 7300	20
Nitric (5%)	> 7300	20	3	20	20	3
<b>Solvents</b>						
Benzene	> 7300	20	20	20	1	1
Xylene	> 7300	20	20	> 7300	1	1
Carbon Tetrachloride	> 7300	20	20	> 7300	1	1
Methyl Isobutyl Ketone	4000	3	20	20	1	1
Butyl Acetate	4000	20	20	20	1	1
Butyl Alcohol	140	20	1	20	20	1
<b>Aqueous Solutions</b>						
Distilled Water	> 7300	170	20	20	20	20
Salt Water (2%)	> 7300	1000	30	30	30	30
Tide Solution (2%)	> 7300	310	> 7300	20	20	20
Chlorox Solution	1000	190	190	110	190	20
Sodium Hydroxide (20%)	190	140	170	50	50	1

## Polyurethane Coatings—

(Continued From Page 93)

spontaneous disintegration or by the ease of coating removal by scraping with the finger nail or knife blade. Some of the coatings are still intact and in excellent condition; these are designated by the symbol (> 7300).

M-1 represents a very resistant type coating. M-4 is a general purpose coating which could be used satisfactorily for the exterior of storage tanks to resist fumes and spillage from the weaker chemicals and solvents and also have excellent weatherability for several years in moderate corrosive environments. The third urethane coating is a simple urethane oil. Coatings E-1 and E-2 are two-component epoxy systems from two different commercial sources, and Coating V is also a commercial article.

### Spot Tests

The spot test gives rapid evaluation of an unknown coating. This usually consists of laying a few drops of corrosive reagent on the cured coating on a flat panel and observing the time for the chemical to have a noticeable effect on the film. This is a useful test but as frequently carried out is apt to be unsatisfactory, particularly if volatile solvents or strong corrosive acids are being used.

A simple refinement of the usual technique consists of cutting small one-inch squares from standard microscope slides and using these to cover the liquid drop. This accomplishes several advantages; a well defined square test area is marked instead of an uneven blob; evaporation of volatile solvents is minimized during the test; and strong acids and liquids of good wetting power do not spread at random over the test surface. Results of these tests confirm data in Table 2.

### Extended Laboratory Testing

The simple spot and glass-probe tests are useful for comparing coatings rapidly in a variety of laboratory liquids. These methods do not give sufficient information for long-term evaluations. Corrosion engineers generally are interested in only a few of these particular exposures, and such methods are not suitable for stricter evaluations in common maintenance applications where resistance to weathering, high humidity, water immersion and petroleum storage, for example, are matters of daily concern.

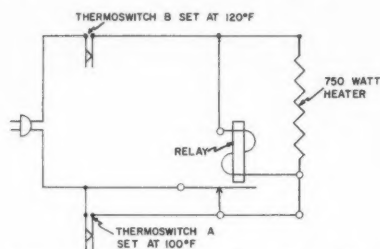


Figure 1—Simple arrangement for heat cycling of humidity tank used in laboratory test on urethane coatings.

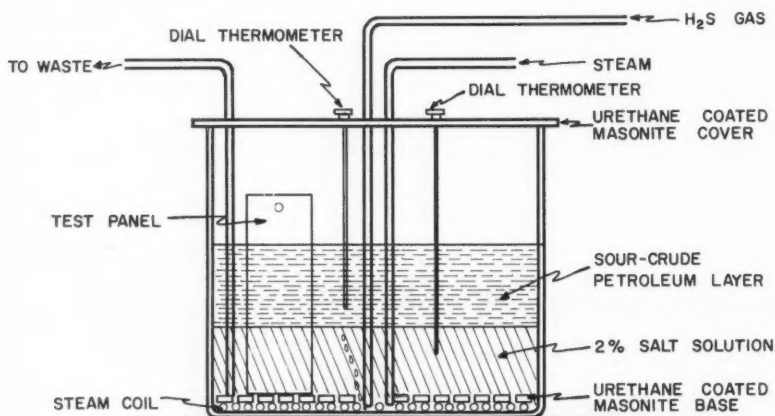


Figure 2—Tank for sour-crude petroleum immersion test for coating samples.

Further testing is needed to provide sufficient evidence of merit to warrant proper consideration of a new coatings system. Such tests require application of a complete coatings system to selected steel panels and immersion in baths for frequent inspection and assessment. In such tests water-immersion at room temperature, high relative humidity at 100 to 120 F and sour-crude petroleum bath at variable temperatures have been used as a basis of comparison.

The humidity bath is a convenient and rapid method for screening corrosion resistant coatings. Most alkyd enamels will blister severely in this test after only a few days exposure.

A common method of conducting a humidity test is to heat a layer of water in the tank bottom so that the vapor above the water is at 100 F. This arrangement is not satisfactory because a constant temperature does not permit alternate condensation and evaporation from the test film. This cycling makes the test a severe one. Furthermore, panels located on the walls get condensation whereas those located in the center of the tank get very little condensation and so results are not comparative. A simple arrangement, which permits cycling of temperature between 100 and 120 F while maintaining relative humidity between 95 and 100 percent can be constructed at low cost using two thermostats, relay and immersion heater as shown in Figure 1.

The heat coil is immersed in one of two inches of water in bottom of a suitable covered tank such as that described below in which the test panels are suspended.

For the water immersion test a glass sided aquarium 24 by 12½ by 13 inches deep was used. Panels were supported from paper clip hooks which passed through a small hole ¼ inch from the center of the short top side. Water immersion tests are commonly made at an elevated temperature such as 100 F, but in the present tests the water was allowed to remain at room temperature throughout. The water level was adjusted so that about ⅔ of each panel was immersed. The upper smaller area serves as a control surface by which effect on submerged areas could be judged.

For testing exposure to sour crude petroleum, the bath arrangement shown in Figure 2 was devised.

Two-thirds of the test panel is immersed. The upper liquid layer is crude petroleum and the lower layer is 2 percent salt solution, since salt water is frequently found associated with petroleum. The bath is heated three times a day to 130 F by the steam coil on the bottom. At the same time H<sub>2</sub>S gas is blown in to maintain a sour solution. Temperature of the petroleum layer rises to approximately 120 F. This also is a severe test because the bottom layer contains not only salt and H<sub>2</sub>S but also ultimately sulphuric acid from oxidation of the H<sub>2</sub>S.

Figure 3 shows the effect of water immersion at room temperature for 5700 hours on a commercial vinyl system shown on the left, a three-coat urethane system in the center and a commercial two-component epoxy system on the right. All films were of a total thickness of 5 to 6 mils on cold rolled steel.

Figure 4 shows the effect of humidity cycling between 100 and 120 F for 2600 hours. The urethane panel is in the center.

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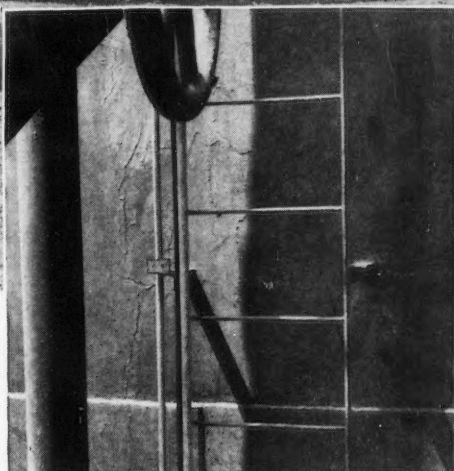
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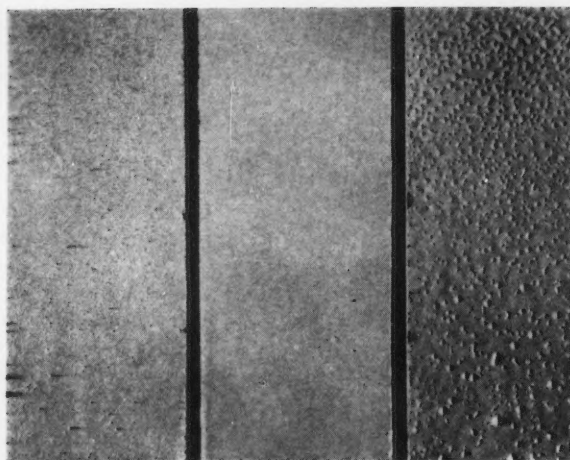


Figure 4—Effect of humidity cycling between 100 and 120 F for 2600 hours. Relative humidity was 95 to 100 percent. Specimen coatings were vinyl (left), 3-coat urethane system (center) and 2-component epoxy system (right).

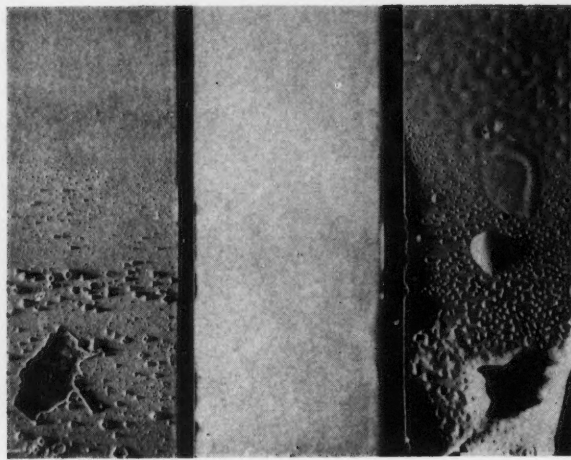


Figure 5—Effect of sour-crude immersion on three coatings samples, exposed for 2600 hours at temperatures between room temperature and 130 F. Specimen on left is vinyl, center is urethane and right is epoxy.

## Polyurethane Coatings—

(Continued From Page 94)

Effect of sour-crude immersion on the same three systems as shown in Figure 5 for 2600 hours at temperature cycling between room temperature and 130 F. Failure of the vinyl and epoxy systems was in evidence at a considerably earlier time than that at which the photographs were taken.

A panel of urethane coating in con-

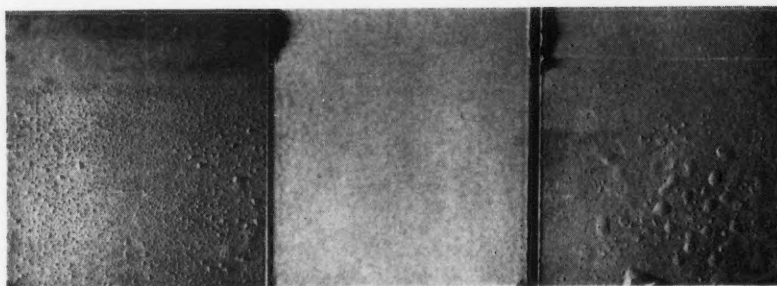


Figure 3—Effect of 5700-hour water immersion on a commercial vinyl system (left), a 3-coat urethane system (center) and a commercial two-component epoxy system (right).

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tinuous water immersion for 13,600 hours (i.e., over 18 months) is shown in Figure 6.

### Conclusions

Urethane coatings may be prepared from non-toxic isocyanate resins in combination with polyesters and other hydroxyl bearing materials such as castor oil and its derivatives. Final coatings are obtainable as a single package and as two-component systems. Durable and corrosion resistant types are prepared from the two-component systems. Some of the two-component systems characteristics are listed below:

1. High gloss and freedom from blushing and surface irregularities.
2. Resistance to weathering.
3. Resistance to water, high humidity, weak solvents and chemicals.
4. Abrasion resistance.
5. Reaction possibilities with orthodox coating raw materials to yield new products.

This combination of properties is needed in the corrosion maintenance and marine fields for the solution of the corrosion engineer's problems.

### Acknowledgments

Thanks are due to G. A. Hudson and J. C. Hixenbaugh who conducted the experimental work described; to Samuel Steingiser and C. F. Crookshanks for photographic assistance; and to Mobay Chemical Company for permission to publish this article.



Figure 6—Urethane coating panel after 18-month water immersion (13,600 hours).

### References

1. Richard C. Burck, Structure, Characteristics and Uses of Urethane Coatings. *Corrosion*, 13, 130 (1957) Dec.
2. Barnard Goodman, New Formulations Give Versatility to Urethane Coatings. *Corrosion*, 15, 100 (1959) April.

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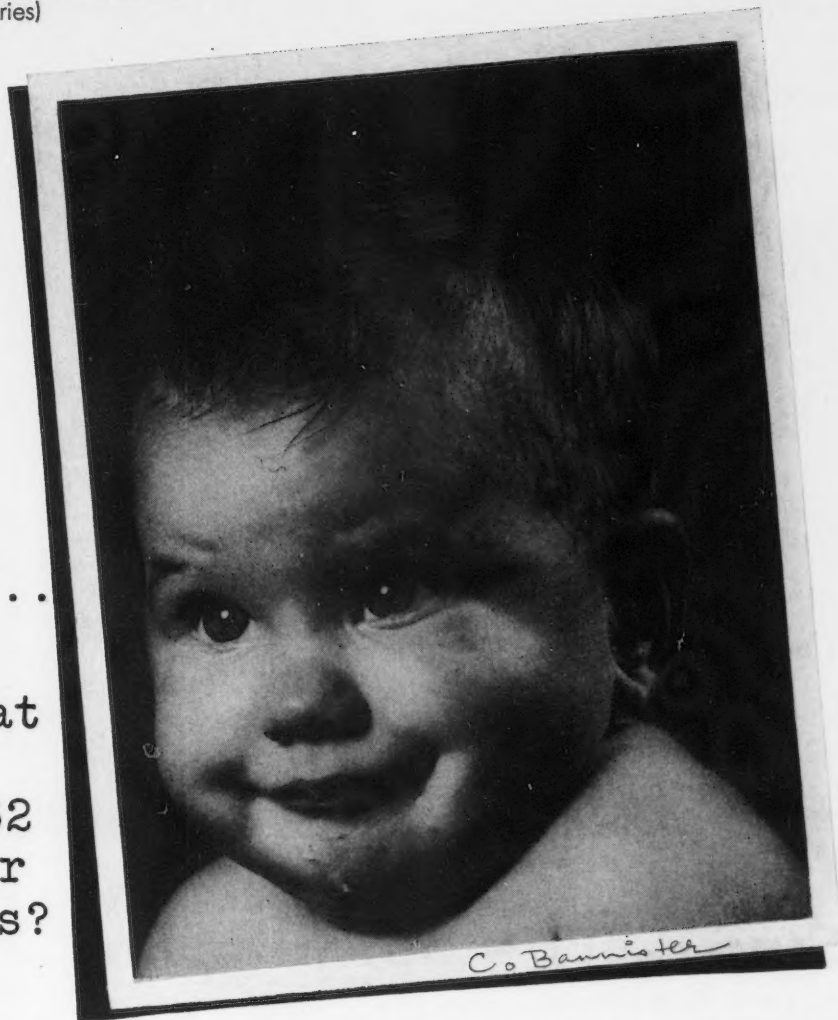
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## Introduction

THE LONG Beach Oil Development Company, an operator for the City of Long Beach in the Wilmington Field, began a pilot water flood project in June, 1953 confined to the upper one-third of the "HX" sand in the Upper Terminal Zone, Fault Block V-B. The top of the "HX" sand is at a vertical depth of approximately 3000 feet. The oil is 18 degrees API gravity with a viscosity of 18 c.p. at reservoir temperature. The zone has a porosity of 37 percent and a brine permeability of 700 md. The pilot block contains 65 productive acres and 1672 acre-feet of oil sand. The main fault block contains 250 productive acres and 25,000 acre-feet of oil sand.

The flood was begun with two directionally drilled injection wells. One was located 1900 feet north and the other 2150 feet south of the surface site. They were completed as follows:

Twelve 3/4-inch surface casing cemented at 354 feet.

Seven-inch, 23 lb and 26 lb, J-55 casing cemented in 10 3/8-inch hole from surface through proposed injection interval.

Seven-inch casing perforated over a 50-foot interval with one 3/8-inch hole per two feet using burrless bullets; 2 1/2-inch tubing landed above top of perforated interval.

Injection was begun with all the water being injected down the tubing.

Injection water for the pilot flood supplied from shallow water wells is similar in analysis to sea water, although it is oxygen free (less than 0.12 ppm) and is free of algae, sea weed, etc. Turbidity is approximately 2 to 3 ppm (as SiO<sub>2</sub>) and because of this it is not filtered.

An analysis of water from one of the source wells is given in Table 1.

Source wells all were completed in a like manner with an 11 3/4-inch to 16-inch liner float packed in 28-inch to 40-inch hole. Gravel size varied from Tyler Mesh 12-14 to a mixture of 6-8 mesh and 3/16-inch gravel. The last of the four wells and the most successful to date was completed as follows:

36-inch conductor pipe driven to 25-feet;

12 3/4-inch steel liner—landed at 195 feet. Liner perforated with 2-inch by 70-inch mesh slots. Liner and perforations coated with a baked-on phenolic plastic 5 mils thick. Liner float packed in 34-inch hole with size 6-8 gravel.

This well recently was redrilled after producing 10,500,000 barrels of water.

One vertical triplex pump was used initially for injection. Three additional pumps, one vertical triplex and two horizontal triplexes were added to the system in May, 1955. The four pumps are capable of an output of 20,000 B/D at approximately 1000 psi pressure. All four have porcelain plungers with aluminum bronze fluid ends.

At the beginning of the flood it was not known if corrosion would be a major problem so the flood was started without a corrosion inhibitor being used in the system. However, it was not long before it was realized that corrosion was a major problem. Some evidence of its seriousness was as follows:

1. The first source well was equipped with a deep well turbine pump with cast

# Corrosion Control Practices in the Wilmington Water Flood Operation\*

## Abstract

Data are given on the method well completion, volume of water injected, types of pumps and lines used in the Wilmington (Cal.) Water Flood Operation. Manner in which effectiveness of inhibitors for injection into salt flood water is described and some of the results achieved with three organic inhibitors are given. Some reports are made on the corrosion resistance of materials used in pumps and well lines and casings. 2.2.7

iron bowls and impellers in May 1953. The pump was discarded in July 1954 as unrepairable because the cast iron components of the pump had graphitized.

2. The original water source well, B-1, was abandoned in April 1955. The 11 3/4-inch liner was recovered and the original 40-mesh perforations had been enlarged to 1/4-inch to 3/8-inch in width due to corrosion and abrasion.

3. The 2 1/2-inch tubing was removed from injection well FZ-228 in October 1954. The tubing had been in service since July 1953 and had 800,000 barrels of water injected down it. Several joints of tubing were split open and an average corrosion rate of 13 MPY was determined.

4. One of the original injection wells was redrilled in February 1957 after receiving over 5 million barrels of injected water. The 7-inch casing string was washed over and recovered to past the top of the injection interval. The lower side of the interior of the casing was found to be severely corroded in a localized area approximately one inch wide from 3774 feet (depth of bottom of tubing from June 1953 to May 1955) to the total recovered depth (3880 feet). The depth of this corrosion increased from 1/2-inch of wall thickness at 3774 feet to the thickness of the casing at 3817 feet. The casing was completely corroded through from 3851 feet to 3852 feet and at 3866 feet.

## History of Chemical Treatment

The first chemicals used in the water injection system (starting in June 1953) were sequestering agents of the polyphosphate type to prevent the precipitation in the formation of barium and strontium. It was subsequently determined that no serious plugging of the formation was occurring even with untreated water so the use of these chemicals was stopped.

Other types of chemicals varied greatly in composition and at various times the following types were used in the system: Arsenic compounds, polyphosphates, sodium hydroxide, sodium hypochlorite and organic compounds.

Of the chemicals tested none but the arsenic and organic compounds proved to be effective corrosion inhibitors. Since March 1955 the only chemicals tested in the system have been organic compounds.

In June 1956 a program was initiated to test laboratory screened inhibitors in the field. The inhibitors had been previously tested in the laboratory for two properties: Bactericidal control and corrosion inhibition.

The procedure used for the bacteriostatic test is the method outlined by Allred, Mills and Fisher. The chemicals were tested for corrosion inhibition in the following manner: A 24-inch wheel containing eleven bottles mounted on its periphery was rotated at six RPM in an oven maintained at 150 F. The chemical being tested was added to the source water in the bottle in the desired concentration. A steel coupon then was placed in the bottle and the bottle sealed. The coupons were tumbled in the bottles on the wheel for five days. A corrosion rate was then determined from the weight loss of the coupons.

The best inhibitors based on the laboratory screening were then tested in the field in the water flood project for six months to a year.

The following tests were used for field evaluation of the inhibitors:

1. Corrosion Coupons. Both insulated and uninsulated. The coupons are located in a discharge line at the source wells and are changed once a month.

2. Millipore Filter Test. Run once a month at the well head of one of the injection wells. The millipore determines the plugging tendency of the water. Also determined from the millipore filters is the amount of filterable solids in the water. A spectrographic determination is run on the solids to determine their probable origin.

3. Water Analysis. Run once a month at the well head of one of the injection wells. The dissolved oxygen, iron and sulfide content of the water are determined.

4. Bacteria Count. A sample of the

(Continued on Page 100)

TABLE 1—Analysis of Injection Water

Radicals	Milligrams Per Liter
Sodium (Na).....	10,525.7
Ammonium (NH <sub>4</sub> )....	.....
Calcium (Ca).....	414.4
Magnesium (Mg)....	1,221.0
Barium (Ba).....	.....
Strontium (Sr).....	.....
Iron (Fe).....	0.2
Sulfate (SO <sub>4</sub> ).....	2,800.0
Chloride (Cl).....	18,295.8
Carbonate (CO <sub>3</sub> )....	.....
Bicarbonate (HCO <sub>3</sub> )..	271.5
Borate (B <sub>4</sub> O <sub>7</sub> ).....	8.7
Iodide (I).....	.....
Silica (SiO <sub>2</sub> ).....	6.3
Salinity as NaCl.....	30,162.3
Total Solids.....	33,543.6
Loss on Ignition.....	4,900.0
Specific Gravity.....	1.025 @ 60 F
Resistivity.....	19.6 Ohm Cm @ 75 F
pH Value.....	7.6

\* Revision of a paper titled "Corrosion Considerations in Wilmington Water Flood Operation" by C. H. Jones, Jr., Long Beach Oil Development Co., Long Beach, Cal., presented at a meeting of the Western Region Conference, National Association of Corrosion Engineers, Nov. 17-20, 1958, Los Angeles, Cal.



## Corrosion Control—

(Continued From Page 99)

water at the injection well is analyzed once a month for sulfate reducing bacteria. The count is reported as so many colonies per ml after 30 days' incubation.

5. Tubing Nipples. Tubing nipples two feet in length are placed at selected locations in the tubing strings of the injection wells. The nipples are cleaned with acid and weighed prior to installation. When the tubing strings are pulled the nipples are cleaned in acid, reweighed and a corrosion rate determined. The corrosion rates determined from the nipples are the best indication of down hole corrosion.

Tables 2, 3 and 4 give a summary of three corrosion inhibitors that have been tested in the water flood system in this manner.

### Flood Expanded in 1958

The Long Beach Oil Development Company expanded its water flood facilities in 1958 to a capacity of approximately 200,000 B/D.

Two new plants recently have been completed, the Pier A plant with a maximum capacity of 120,000 B/D and the Pier E plant a capacity of 70,000 B/D. Both are similar in design. Shallow source wells are drilled in the immediate area to supply the water. First source wells in the area were completed in a manner similar to that used for the last well completed on Pier B.

After 36-inch conductor pipe was driven to 25 feet, a 34-inch hole was drilled to about 150 feet; 12¾-inch steel liner was perforated with 70-mesh slots and coated inside and out with a baked-on phenolic plastic. The liner was float packed in the 34-inch hole with size Tyler mesh 6-8 gravel. The deep well turbine pumps used are composed of either nickel alloyed cast iron or SAE-63 bronze material throughout. The shaft driven pumps have 18-8 stainless steel shafting with SAE-63 bronze spiders. The pump columns in the new wells were of wrought iron. It was soon evident that wrought iron was not a non-corrosive material in the water flood system. The 5-inch wrought iron pump column in one source well was discarded after 3½ months' service because of severe corrosion. The well averaged pumping 11,000 B/D during the period. The 5-inch wrought iron pump column in another well pumping approximately 12,000 B/D lasted five months before being discarded. The wrought iron columns have been replaced with steel columns coated inside and out with a baked-on phenolic plastic.

The last four source wells at the new plants were completed with concrete liners. The wells are drilled with a reverse circulation rig which eliminates the use of drilling muds, using as fluid in the operation salt water obtained from other source wells. This eliminates the need of swabbing the wells to remove the mud filter cake and allows the use of larger perforations and a more carefully designed and placed gravel pack which results in better sand control of the produced water. The method also eliminates one possible source of solids (clays in the mud) that could act as a plugging agent in the injection wells. On the basis of limited experience it now appears that this is the most suitable type of completion.

### Water Pumped to Tanks

From the source wells the water is pumped through asbestos-cement lines to 3000-barrel storage tanks. The nine tanks are coated inside with a coal tar product. The water moves by gravity from the tanks through a 22-inch steel line (coated inside with a coal tar product) to the injection plant where it is pumped by the injection pumps to the individual injection wells. Asbestos-cement pipe and coated steel lines are used in the low pressure water system where feasible.

Both plants are equipped with 500 HP horizontal quintuplexes equipped with either 4-inch or 5-inch solid ceramic plungers. The fluid ends of the pumps are aluminum bronze with stainless steel valves and seats. The pumps are powered with 500 HP natural gas engines.

The water is pumped by the injection pumps into a two-pressure system. The high pressure pumps (4-inch plungers) pump into a system with a maximum pressure rating of 2000 psi. The low pressure pumps (5-inch plungers) pump into a system with a 1270 psi maximum pressure rating.

Each injection well is coupled into the manifold system so that water can be taken from either the high or low pressure system. The volume of water to each well is controlled by an adjustable flow bean with a maximum opening of 2¼ inches. The conical tips and seats of the beans are tungsten carbide. All

lines from the injection pumps to the injection wells are steel with no protective coatings.

The injection wells have all been completed in a like manner: 9¾-inch J-55 casing cemented at the top of the zone; 7-inch J-55 casing cemented through the proposed injection interval; 7-inch casing is perforated in the desired injection interval with ¾-inch jet shots at an average of two holes per foot.

The injection wells are completed without tubing in the hole with the water injected directly down the casing. The volume of water injected into each well varies from a 1000 to a maximum of 35,000 B/D. As high as 70,000 B/D has been injected into a single well during a test period.

### Steel Pipe Used Primarily

As previously mentioned non-corrosive materials have been used in several locations in the injection system. However, the injection well casings and the discharge lines from the injection pumps are steel pipe. To protect this pipe an organic corrosion inhibitor is added to the water in each system before it enters the storage tanks. The corrosion inhibitor injection system at each plant consists of a 250-barrel storage tank, an electrical chemical pump for pumping the chemical from the storage tank into the system, and a positive displacement meter for measuring the amount of daily

(Continued on Page 102)

TABLE 2—Corrosion Coupon Tests

	INHIBITOR		
	A	B	C
Type .....	amine	amine	amine
Concentration .....	20 ppm	20 ppm	14 ppm
Cost .....	2.63 M/B	2.0 M/B	2.0 M/B
Period Tested .....	3-56 to 12-56	1-57 to 4-58	4-58 to Present
<b>Water Source Well B-3</b>	<b>mpy</b>	<b>mpy</b>	<b>mpy</b>
Holder No. 1			
Insulated .....	1.6	1.4	9.5
Uninsulated .....	8.4	22.5	36.1
Holder No. 2			
Insulated .....	0.89	2.5	2.1
Uninsulated .....	5.6	15.0	15.0
<b>Water Source Well B-4</b>			
Insulated .....	4.2	0.4	12.7
Uninsulated .....	96.0	3/5	*

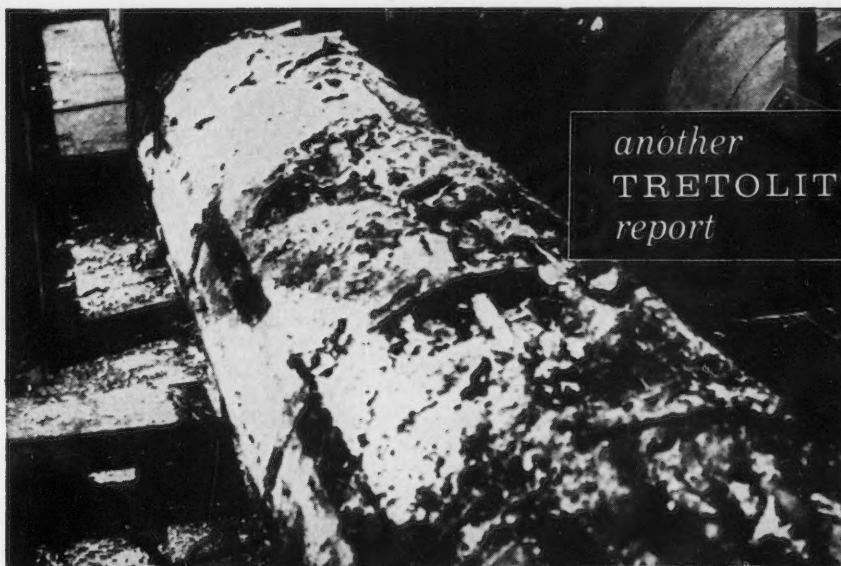
\* No coupons remaining. Five tests (1).

TABLE 3—Water Quality Tests

	INHIBITOR		
	A	B	C
Slope of Millipore Curve .....	0.246	0.202	0.624
Filterable Solids .....	3.8 mg/l	5.5 mg/l	2.7 mg/l
Oxygen .....	0.0 ± (0.12)	0.0 ± (0.12)	0.0 ± (0.12)
Sulfides .....	0.03 mg/l	0.02 mg/l	0.13 mg/l
Iron .....	2.3 mg/l	2.2 mg/l	1.3 mg/l
Sulfate Reducing Bacteria .....	Not Reported	136 Col/ml	106 col/ml

TABLE 4—Tubing Nipple Tests

Inhibitor	Period Nipples In Service	Well FZ-228		Well FZ-229	
		Bbl Water Injected	Corrosion Rate mpy	Bbl Water Injected	Corrosion Rate mpy
A .....	8-56—1-57	No Nipples	0.3	1,157,270	2.9
B .....	3-57—2-58 (FZ-228)			3,378,869	0.3
C .....	1-57—2-58 (FZ-229)	No Nipples	..	2,078,614	3.6
	2-58-10-58				



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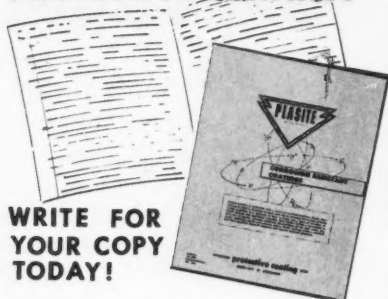
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## Corrosion Control—

(Continued From Page 100)

injected chemical. The large storage capacity permits the buying of the inhibitor in bulk quantities resulting in a considerable savings. The present inhibitor is being used at a concentration of 20 ppm at an approximate treating cost of 1.55 mills per barrel of injected water.

Effectiveness of the inhibitor in the new systems will be checked by the methods previously used for the pilot flood. It is not planned to use the tubing nipples because no tubing is being used in the injection wells.

Research also is continuing on the use of non-corrosive materials in the system where possible. However, it appears that steel casing will be required in the injection wells and that this will necessitate continued use of corrosion inhibitors.

### References

1. Bacteriological Techniques Applicable to the Control of Sulfate Reducing Bacteria in Water Flooding Operations. *Producer's Monthly*, December, 1954.

### DISCUSSIONS

**Question by Joe Chittum, Whittier, Cal.:**

Was there plugging from corrosion products? What kind of plugging? Was plugging encountered in injection wells during time corrosion was experienced? What was the evidence for plugging?

**Reply by C. H. Jones, Jr.:**

The water injection wells have continually suffered a loss in injectivity as shown by the loss in injection rate at a constant pressure. It has been possible to restore the injection wells injectivity by backflowing. This indicates the loss of injectivity is caused by plugging.

Prior to the use of corrosion inhibitors in the system, material backflowed from the injection wells contained primarily iron compounds. This indicated the nature of the plugging material to be corrosion products.

However, since using organic corrosion inhibitors, the plugging material appears to be a mixture of the hydrocarbon carrier used in the inhibitor and fine silts and sands produced from the water source wells. The amount of iron compounds found in the plugging material is very minor.

**Question by Brian R. Jackson, Santa Fe Springs, Cal.:**

Of the three inhibitors tested, was Inhibitor C the least water-dispersible?

**Reply by C. H. Jones, Jr.:**

Yes.

**Question by Gordon S. Schuhmacher, South Gate, Cal.:**

Iron in source water. Analysis of source water 0.2 ppm Fe and input water over 2.0 ppm Fe. Any comment on how to account for increase?

**Reply by C. H. Jones, Jr.:**

Additional data indicate no change in iron content between source well and injection well. The 0.2 ppm of iron reported at the source well is in error because it represents a test run on filtered water. Filterable iron compounds would have been removed.

**Questions by L. W. Jones, Pan American Petroleum Corp., Tulsa, Okla.:**

1. Test for oxygen: What analytical method is used for measuring oxygen content of the source water?

2. Are all the inhibitors tested considered to be soluble in the source water?

**Reply by C. H. Jones, Jr.:**

1. The analytical method used for measuring oxygen content is the ASTM Umpire Method (D888-49T).

2. All the inhibitors tested are considered to be water dispersible.

**Questions by E. W. Wallace, Los Angeles, Cal.:**

How were the concrete liners in the source wells perforated? What were inhibitors? What are the names of the inhibitors referred to as A, B and C? How do you know you plug 700 md. sand? How do you explain the plugging of a 700 md. sand formation? Is this the permeability of the extracted core? How do you clean out wells after plugging? What proceeding is used to restore injectivity in wells that are plugged?

**Reply by C. H. Jones, Jr.:**

1. The concrete liners were precast with 125 mesh slots. The liners are manufactured by the Kelly Well Company at Grand Island, Nebraska.

2. Company policy prevents our giving the names of products we evaluated.

3. It is known that the highly permeable sands plug by the loss of injectivity in the injection wells. The plugging material appears to be a combination of the hydrocarbon inhibitor carrier and fine silts and clays present in the source water.

3. The injectivity of the wells is restored by backflowing the wells using a formation tester. This method has proved effective in restoring the injectivity to as high or higher than the original injectivity.

4. The permeability figures are brine permeabilities run on 100 percent wet sands. Extraction would not be necessary as no hydrocarbons are present.

**Question by A. V. Louk, Santa Fe Springs, Cal.:**

In testing your flood water for plugging tendencies with a Millipore filter, does the water tested contain the inhibitor used and have you evidenced any plugging attributable to the inhibitor used?

**Reply by C. H. Jones, Jr.:**

The millipore filter tests are run on water treated with inhibitor. They do not indicate a plugging tendency by the inhibitor. However, there is evidence that the inhibitor carrier in combination with fine silts and clays is responsible for loss of injectivity in the injection wells.

**Questions by Willard R. Scott, Magna Products, Inc., Santa Fe Springs, Cal.:**

1. Are you satisfied that the oxygen content of the water is essentially zero at all times, even though an analysis is made only once a month?

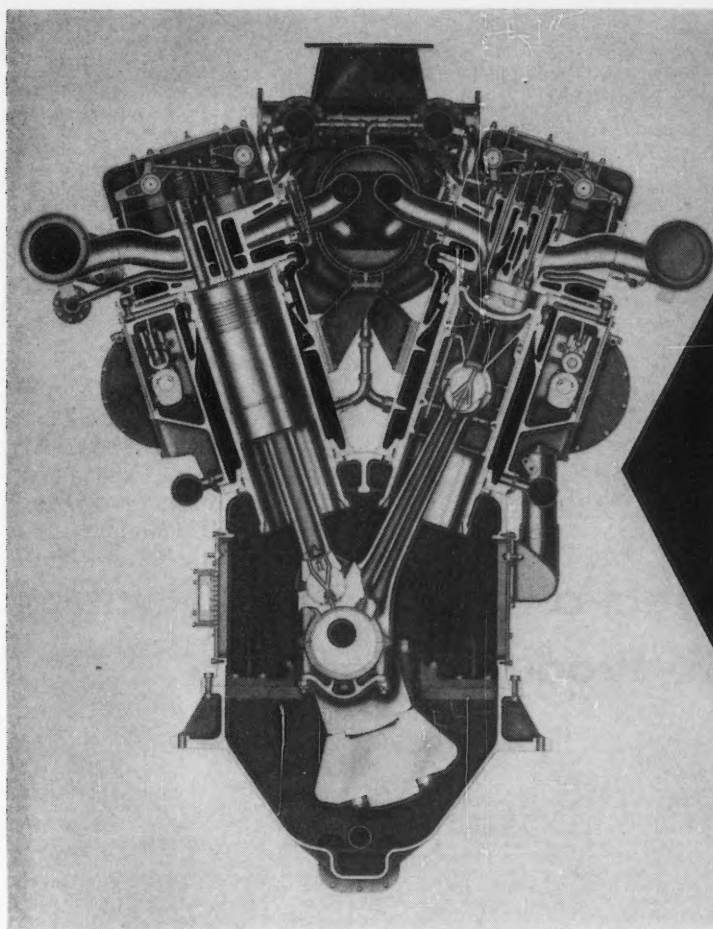
2. What do you believe to be the mechanism of the corrosion observed in the absence of effective inhibitors?

**Reply by C. H. Jones, Jr.:**

1. Yes.

2. Analysis of the water shows about 35 ppm CO<sub>2</sub> and the presence of sulfate reducing bacteria.





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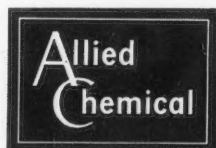
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During 1957 the pipeline system was expanded by construction of a new 10, 8 and 6-inch products pipe line between Richmond in the San Francisco Bay area and Reno, Nevada, with a 6-inch lateral to Fallon, Nevada. This new system, including laterals, totals 347 miles.

Designed through-put for the new system is 15,000 barrels per day from Richmond to Reno. With planned ad-

ditional pump units, this rate can be increased to 20,500 barrels per day with a 42,000 barrels per day capacity as far as Roseville.

ous region which is snowed-in during winter and spring and is not easily accessible at any time. Because the environment in any of these areas could be extremely corrosive, a cathodic protection system had to be put in operation as soon as possible with an absolute deadline in the mountains coinciding with the first snows of the 1958-1959 winter. Tests begun in February, 1958, showed coating resistance was not as high as expected. Although rock-shield had been used in the rocky areas, rocks damaged the coating in a number of locations. After completion of construction when the line was hydrostatically tested, numerous leaks were found in the section of 10-inch pipe between Concord and Roseville. Many of these were small and not easily pin-pointed, so the line had to be probed so that a vibration recording leak detector could be used. In

were unusual. The first was that of satisfying fairly large current requirements at terminals without causing interference to nearby foreign substructures such as railroads, refineries and other pipe lines. Because it was impossible to install the anodes at great distances from these foreign substructures, the anodes were installed quite close to company facilities (within 5 to 10 feet at times), and the anodes were made large enough so that the resistance was so low that there were practically no anode fields. Large anode beds were over 1400 feet long. Resistance was so low that potential between anode and pipe was about the same as pipe-to-soil potential, some times 1.5 to 2.0 volts.

The second problem was to get protection on the section of the pipe line in the High Sierras. The line crosses over Donner Pass and for a distance of ap-

## Whole System Installed in Nine Months

# Cathodic Protection of Southern Pacific's High-Pressure Products Pipe Line\*

### Abstract

Various problems encountered and methods used to achieve cathodic protection of a pipe line across central California and Nevada are discussed. Location of rectifiers and anodes used are given. Special problems such as the winter snows, air observation of rectifiers and close proximity to co-axial telephone cable are discussed. 5.2

ditional pump units, this rate can be increased to 20,500 barrels per day with a 42,000 barrels per day capacity as far as Roseville.

This line, which transports regular, premium and aviation gasoline plus diesel oil and jet fuel, operates at high pressure so the product can be pumped over the High Sierras. For example, on the western slope of the mountains near Colfax, California, discharge pressure at one of the pump stations is 2160 psi.

### Coating System Used

Four different systems of coating materials were used on the pipe. In general, 1/2-inch plant-applied asphalt base coating was used on all river crossings and major hot spots. Plant-applied double-coat, double-wrap asphalt coating consisting of asphalt primer, enamel with 13-pound asphalt saturated rag felt followed by 20-pound asphalt saturated rag felt, was used in the heavily congested areas. Plant-applied, single-coat, reinforced, single-wrap asphalt coating was used throughout the remainder of the system except for a few short sections in which over-the-ditch wrapping was allowed.

A portion of the line near the coast is under water most of the time. In another area, many miles of the line are through peat lands where the line crosses several rivers and marsh areas. Much of the line is laid alternately through wet and dry areas in farming country, and many more miles are lying in very low resistivity alkali flats where water is present most of the time. In addition, many miles traverse a rough mountain-

some cases, probing was done at no greater than 2-foot intervals. The resultant holidays were not repaired. In addition to the holidays, a number of locations were found where the coating is not adequately bounded to the pipe.

### Cathodic Protection Design

Due to scarcity of usable routes through the Sierras, the pipe line was laid near and closely parallel to an existing co-axial telephone cable. To minimize interference to the cable and to preserve the pipe coating as long as possible, a maximum pipe-to-soil potential of 1.5 volts was decided on. This meant that a greater than normal number of rectifier units was required.

One cathodic protection rectifier unit was designed for each of six terminals and pump stations. Because more current was required at these spots, they were good starting points. Also, no right-of-way problems were involved because all anode beds could be installed on company properties. When these units were installed and operating, locations were selected for the remaining units in the pipeline runs between the terminals and pump stations. Some of the required current was purchased from owners of nearby existing cathodic protection stations, and 21 additional units were installed.

### Two Unusual Problem Solutions

Although many of these units were quite ordinary, two problem solutions

proximately 60 miles is either very remote from power or is laid in solid granite. It was determined that three units would be needed in this heavy snow country. The first, with no unusual problems, was installed near Truckee, California, using scrap rail for the anode.

The second unit had to be located near the only available power and was installed in the conventional manner, except for high resistance soil, using 10 horizontal graphite anodes in a coke backfill. This unit operates at 0.9 ampere and 110 volts d-c output or with an anode resistance of approximately 124 ohms as compared with resistances of 1/10 ohm in the low altitude marsh country.

The site for the third high-country unit was the most difficult of the three units. For the entire distance along which this unit could operate effectively, the pipe line was in granite. However, there was a lake close to the line in which the anode was installed. Due to limited space and especially level cleared ground, the anode was formed of threaded and coupled 3-inch pipe, floated onto the lake as it was assembled. Resistivity of the water in mountain lakes is not as low as might be expected. In this case, it is over 40,000 ohm-cm.

Because of the deep snowpack during winter months, rectifiers were mounted near the tops of poles, with platforms 20 feet high on which to work.

Because the line is patrolled weekly by airplane, failure indicators are being installed for pilot observation on all rectifier units not at a manned terminal or pumping station. Most failure indicators are electric motor driven discs which are connected to the a-c side of the rectifier. As long as the rectifier receives its a-c supply, the disc revolves

(Continued on Page 106)

\*A revision of the paper "Blitzkrieg Cathodic Protection of a High Pressure Products Pipe Line" by D. N. Miller, Southern Pacific Lines, Inc., Los Angeles, Cal., presented at the 15th Annual Conference, National Association of Corrosion Engineers, Chicago, March 16-20, 1959.

## Cathodic Protection

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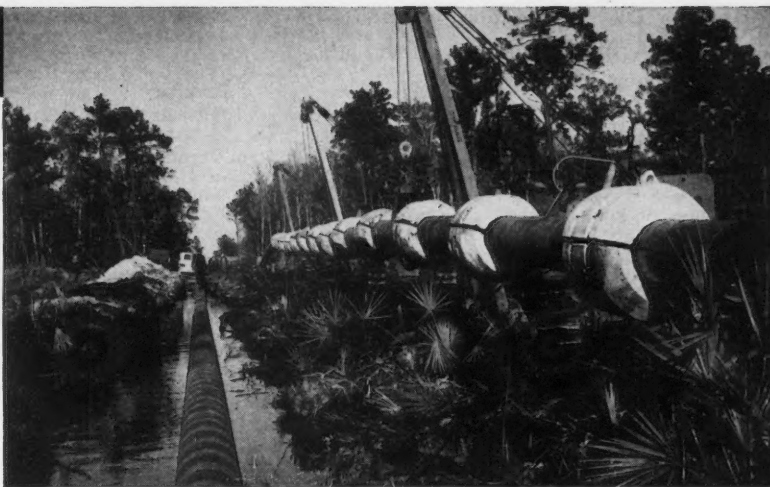
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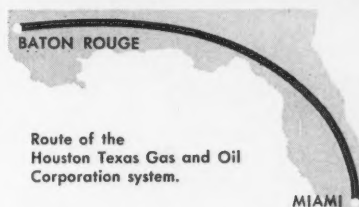


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River weights on Polyken coated 24" line going into the swamps of Florida.



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## Cathodic Protection—

(Continued From Page 104)

to indicate presumably satisfactory operation. This type of indicator can show the rectifier in service while the d-c circuit is open.

Because it is more important to know that the pipe line is receiving an adequate supply of direct current, indicators were designed to operate on a-c but are controlled also by the d-c. A failure in either the a-c or d-c circuit will cause the indicator to stop revolving. This is accomplished by using a relay which is actuated by a meter relay hooked across the rectifier output shunt. When the relay is closed, an a-c motor turns the indicator. The indicator is

shaped like a cone so that it sheds snow and can be seen from both the ground and the air.

### Summary

Several things have been accomplished:

1. The 21 units required to protect the lines are installed and operating—20 of these were in operation within 9 months of the first design attempts.

2. If anodes need to be installed in water again, experience gained will permit avoiding many pitfalls.

3. The overall cathodic protection system, completely designed, installed and put into operation in less than one year will provide complete protection for the pipeline system at a reasonable cost.

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## DISCUSSIONS

**Glass Fiber Reinforcement for Coatings**, by B. A. Graham. *Corrosion*, Vol. 15, No. 4, 102-104 (1959) April.

**Question by Austin K. Long**, Glidden Company, Bay Village, Ohio:

Would the author comment on simultaneous application of sprayed coating and fibers in the reinforced plastics field?

**Reply by B. A. Graham:**

The simultaneous application of sprayed resin and fibers has a definite place in the reinforced plastics field. It is not a cure-all but is an improvement over hand lay-up methods in many cases. I believe it will find its place in short production runs which do not warrant the expense of matched metal dies and also for shapes which are difficult to tailor with cloth or chopped strand mat.

**Question by Sol M. Gleser**, Cincinnati, Ohio:

What is your recommendation for mats to reinforce thin epoxy coatings for protection of concrete floors.

**Reply by B. A. Graham:**

Because of a limited knowledge of this particular application, I cannot make a recommendation. I will suggest that monofilament mats are worthy of evaluation. The epoxy coating thickness should be greater than the mat thickness, which means greater than 10 mils.

**Methods of Installing Cathodic Protection Anodes for Offshore Structures**, by Wayne A. Johnson and James T. Condry. *Corrosion*, Vol. 15, No. 9, 112 (1959) Sept.

**Question by Dean C. Glass**, Chicago, Illinois:

What type electrode is used to check water to steel potential and where is the electrode positioned with respect to the structure (protected) on the typical installation as described?

**Reply by Wayne A. Johnson:**

We generally use a calomel electrode and place it several inches from the structure, obtaining readings at several levels in the water.

**Questions by Robert L. Davis**, South Pasadena, California:

1. Have you investigated suspending magnesium anodes on plastic rope?

2. Have you had any trouble with failure of graphite anodes at the lead wire connection.

**Reply by Wayne A. Johnson:**

1. We have had better service with steel cables or Monel if the lengths are not long enough to add excessive resistance to the anode circuit. Nylon rope stretches too much. Polyethylene rope does not stretch as much as nylon. Using plastic ropes, you still need an electrical conductor.

2. Wire connections to the graphite anode are always subject to failure due to penetration by water. We try to get the best type of waterproof joint. We usually cap the top with an epoxy.

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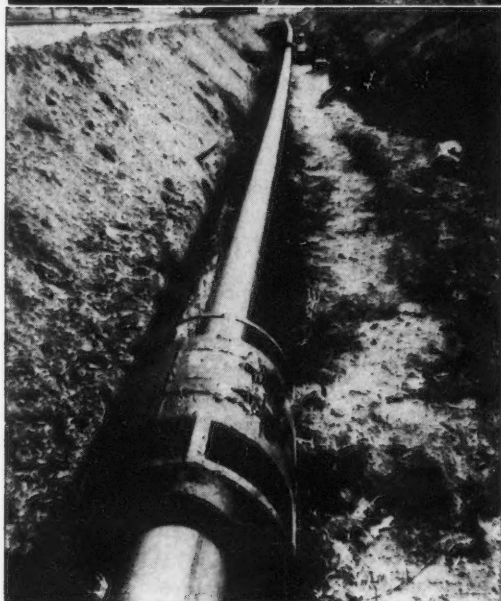
  
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# CORROSION ABSTRACTS

## INDEX TO CORROSION ABSTRACTS

Vol. 15 December, 1959 No. 12

### 3. CHARACTERISTIC CORROSION PHENOMENA

- 3.2 Forms ..... 109
- 3.5 Physical and Mechanical Effects... 110
- 3.6 Electrochemical Effects ..... 110
- 3.7 Metallurgical Effects ..... 112
- 3.8 Miscellaneous Principles ..... 112

### 6. MATERIALS OF CONSTRUCTION

- 6.2 Ferrous Metals and Alloys..... 113
- 6.3 Non-Ferrous Metals and Alloys—Heavy ..... 114

### 8. INDUSTRIES

- 8.4 Group 4 ..... 116
- 8.7 Group 7 ..... 116
- 8.8 Group 8 ..... 116
- 8.10 Group 10 ..... 120

### 3. CHARACTERISTIC CORROSION PHENOMENA

#### 3.2 Forms

##### 3.2.2, 3.8.4

Behavior of Hydrogen in Iron (Steel). A. Smialowski. Neue Hütte, 2, No. 10, 621-626 (1957). Translation available from Henry Brucher, Technical Translations, P. O. Box 157, Altadena, California.

Gaps in our present knowledge of the behavior of hydrogen in iron and steel. Expansion of iron (steel) due to penetration of hydrogen into it, and results of calculations based on measurements of pressure exerted by cathodically liberated hydrogen. Deviation of diffusion coefficient measured at room temperature from values extrapolated from higher temperatures and the associated problem of the conjectured two desorption stages. Probable effect of 'blowhole layer' on the observed values of the diffusion coefficients at room temperature. Nucleation of blowholes. Presence of hydrogen in the iron lattice in the atomic as against the ionic form. 'Metallic' hydrogen. Migration of hydrogen in iron under an electrical potential gradient. Correct thickness of wires and membranes used for measuring hydrogen desorption and penetration, respectively, and, hence, diffusion coefficients at room temperature, as a most important factor in avoiding erroneous conclusions. 6 figures, 1 table.—HB. 16281

##### 3.2.2, 3.7.3, 6.2.5

Anneal Stainless Tubing for Corrosive Use. J. S. Adelson. Republic Steel Corp. Iron Age, 182, No. 6, 83-85 (1958) August 7.

The main cause of failure in stainless steel tubes are intergranular corrosion, stress-corrosion cracking and pitting. For this reason tubing made from 300

series stainless steels should be given a final solution heat treatment at 1850 to 2050 F after welding or cold forming. The use of a bright annealing furnace for heat treatment so that the original smooth tubing surface is retained is recommended. It is pointed out that the prevention of failures in handling corrosive materials offsets the extra cost of the annealed product.—NSA. 16740

##### 3.2.2, 6.3.11

Origin and Mode of Formation of Certain Local Stains on Silver Tableware. D. Birtles, E. Jackson and M. Thomson. Nature, 179, No. 4559, 557-559 (1957).

When sodium chloride is dropped on a silver surface immersed in hot water containing certain synthetic detergents, it produces local dark spots, which cannot be removed by the proprietary dip cleaners or the aluminum-soda process. Similar stains are produced by sodium

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JSPS—Japan Society for the Promotion of Science, Mr. Hayata Shigeno, Secretary, Committee of Preventing Corrosion, c/o Government Chemical Industrial Research Institute, 1 Chome Nakameguro, Meguro-Ku, Tokyo, Japan.

MA—Metallurgical Abstracts, Institute of Metals, 17 Belgrave Sq., London, SW 1, England

NSA—Nuclear Science Abstracts, United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tennessee.

OTS—Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

PDA—Prevention of Deterioration Abstracts, National Research Council, 2101 Constitution Ave., Washington 25, D. C.

PMR—Platinum Metals Review, Johnson, Matthey and Co., Ltd., Hatton Garden, London, ECI.

RML—Review of Metal Literature, American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio.

RPI—Review of Current Literature Relating to the Paint Colour, Varnish and Allied Industries, Research Assoc. of British Paint, Colour and Varnish Manufacturers, Paint Research Station, Waldegrave Rd., Teddington, Middlesex, England.

SE—Stahl und Eisen, Verlag Stahlisen, m.b.H., Breite Strasse 27 (Schliessfach 2590), Dusseldorf, Germany.

TIME—Transactions of The Institute of Marine Engineers, The Memorial Bldg., 76 Mark Lane, London E. C. 3, England.

WR—Wear, Elsevier Publishing Co., 110-112 Spuistraat, Amsterdam, Holland.

ZDA—ZDA Abstracts, Zinc Development Association, 34 Berkeley Square, London W. 1, England.

chloride particles on silver immersed in dilute acid or alkaline solutions, or merely in water, but not by an homogeneous sodium chloride solution; similar stains are produced by potassium chloride, ammonium chloride, potassium bromide, or sodium iodide, but not by sodium fluoride. Of 5 solid detergents tested, the only one that did not produce a stain had the lowest halide content. The stains are composed of silver chloride, silver bromide, or silver iodide. The recent increased occurrence of the stains is partly due to the chemically clean surface exposed by the detergent to sodium chloride particles. The essential requirement for stain formation is a local concentration of halide at a silver surface, which promotes electrochemical action.  $CN^-$  and  $CNS^-$ , which, like  $Cl^-$ ,  $Br^-$ , and  $I^-$ , form insoluble silver compounds soluble in excess anion, give similar stains. To prevent staining, the detergent should be dissolved before the silver, freed from sodium chloride by previous washing, is immersed.—MA. 14593

### 3.5 Physical and Mechanical Effects

#### 3.5.3

**Selecting Materials to Avoid Cavitation Damage.** William J. Rheingans. *Materials in Design Engineering*, 48, 102-106 (1958) Sept.

Various types of stainless steel and aluminum bronze provide the best resistance to cavitation erosion in hydraulic equipment. There is a wide variation in the resistance of similar materials, and a small change in a material's chemical content or properties can substantially affect its resistance to cavitation damage.—MR. 16860



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#### 3.5.4, 4.7

**Transport of Radioactivity by Liquid Sodium in a Stainless Steel Circulation System.** D. Fieno and D. Bogart. U. S. National Advisory Cttee. Aeronautics, Research Memo., E54K03, 1955 (Declassified, 1957), 17 pp.

Data were obtained for toroids operating at 900 F (480 C) at a constant sodium velocity of 15 ft/sec. Irradiated 316 or 347 stainless-steel inserts were placed in the toroids. The activity transfer was limited by the diffusion of activated atoms. The transfer from the insert to the toroid wall increased with increase in sodium oxide content of sodium. A 600-hr experiment implying a temperature differential in the toroid resulted in no change after a 1400-hr isothermal run.—MA. 16205

#### 3.5.7, 3.5.8

**The Influence of Hydrostatic Pressure on the Tensile Deformation of Single Crystals.** P. Haasen and A. W. Lawson, Jr. *Z. Metallkunde*, 49, No. 6, 280-291 (1958) June.

Effect of 5000 atm hydrostatic pressure on tensile stress-strain curve was investigated on single crystals of aluminum, copper, nickel and alpha-brass as well as on polycrystalline nickel. In all cases except nickel single crystals the flow stress increases with pressure. Increase is larger than is expected from change in elastic moduli with pressure. Returning to deformation at 1 atm following strain at 5000 atm the flow stress is still higher than normal. In pure metals rise in flow stress under pressure is interpreted in terms of work done against pressure to produce volume. Volume change due to plastic deformation follows to about  $10^{-4}$ . Residual increase in flow stress at 1 atm after deformation under pressure shows that crystal workhardens more strongly under pressure in favor of decreased volume production. Dislocation theory is discussed. Investigation on zinc single crystals shows that hydrostatic pressure has no effect on deformation twinning. Graphs.—INCO. 16525

#### 3.5.8, 3.5.9, 4.6.2, 6.2.5

**Stress Corrosion Cracking of Austenitic Steels at Elevated Temperatures and Pressures.** V. P. Sidorov and A. V. Ryabchenko. *Metallurg*, 1 Obrabotka Metallov, No. 6, 25-32 (1958) June. Translation Available from Henry Bratcher, Technical Translations, P. O. Box 157, Altadena, California.

Development of a long-time test for stress corrosion resistance in aqueous solutions, of steam superheater and steam-pipe steels, simulating their conditions of service. Particulars on authors' testing machine. Steel compositions (austenitic) tested. Effect of composition and concentration of test solutions, with and without access of oxygen; concentration of solutions below which steel does not succumb to stress corrosion failure. Effect of testing temperature; range in which stress corrosion occurs; relation between test temperature and time to failure. Stress corrosion resistance as affected by heat treating; true nature of effect of heat treating. Influence of sodium chloride addition to sodium hydroxide solution. 7 figures.—HB. 16645

#### 3.5.8, 2.3.7

**Relations Between Direct-Stress and Bending Fatigue of High-Strength Steels.** G. Sachs and G. Scheven. *Syracuse Univ. Proc. Am. Soc. Testing Materials*, 57, 667-681 (1957).

Results of fatigue tests on SAE 4340 heat treated to 210,000 psi and 290,000 psi and tested under various conditions. Direct-stress and rotating-bend tests on smooth and notched specimens were performed leading to failure at ranges between a few and about one million cycles. Each S-N curve extrapolates well to respective static strength of origin. Two characteristic quantities were determined for various cycles: ratio of strength in bending to that in tension (bend-strength ratio) and ratio of strengths of notched to smooth specimens (notch-strength ratio). Bend-strength ratio for high numbers of cycles is practically equal to unity, while for low numbers of cycles it is larger than 2 for smooth specimens and between 1-2 for notched specimens, depending on their ductility. Tables, graphs.—INCO. 16337

#### 3.5.8, 2.3.7

**Study of Corrosion Fatigue; Method of Measuring Damage Caused by Corrosion Fatigue.** (In Japanese.) Kanetoshi Iwamoto. *Trans. Soc. Mech. Engrs., Japan*, 23, 238-241 (1957) March.

After specimens were corroded with a water steam under various magnitudes of rotary bending stress and for various times, they were subjected to fatigue tests in air under a stress, which was about 20 per cent larger than the fatigue limit of the material.—MR. 14686

### 3.6 Electrochemical Effects

#### 3.6.8, 3.2.2

**Hydrogen Embrittlement of Steel During Cathodic Treatment.** M. A. Figelman and A. V. Shreider. *J. Applied Chem. USSR (Zhur. Priklad. Khim.)* 31, No. 8, 1184-1193 (1958).

Effect of duration of cathodic polarization in sulfuric acid and sodium hydroxide, thickness of zinc coating, Chrome-plating conditions, soaking at various temperatures on brittleness of steels is investigated. 1 table, 6 figures, 12 references.—ATS. 16488

#### 3.6.8, 3.8.3

**Electrochemical Properties and Corrosion Rate of Intermetallic Compounds.** N. Ohtani. *J. Japan Inst. Metals*, 22, No. 4, 212-216 (1958) April.

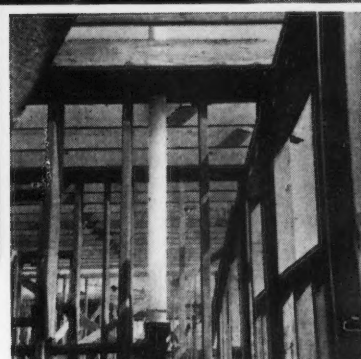
The electrochemical properties, especially the anodic polarization and the hydrogen overpotential of intermetallic compounds were measured; the anodic polarization was approximately equal to the mathematical mean of two components of the compounds, but the larger the electronegative difference of the components and the higher the melting point of the compound, the smaller was the hydrogen overpotential of the compound. The relation between corrosion rate, anodic polarization and hydrogen overpotential of various alloys in which compounds are formed, was found to be in fair agreement with results of previous reports.—JSPS. 16597

#### 3.6.6

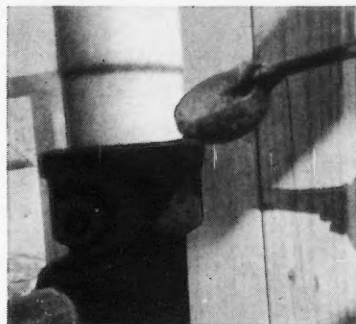
**Corrosion of Metals Connected to Graphite Components.** T. K. Ross. *British Chem. Eng.*, 3 368-370 (1958) July.

Metallic plant components connected to graphite equipment may, in service, undergo severe corrosion. An investigation of this problem and how it can be controlled is discussed.—BTR. 16600





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**3.6.6, 3.6.2, 3.6.9**

**Galvanic Corrosion.** J. Boraston. *Inspection Engineer*, 22, 50-56 (1958) May-June.

Causes, prevention of dissimilar metal corrosion, crevice corrosion, stray current corrosion, 4 references.—MR. 16462

**3.6.8**

**Surface Distribution of the Working Efficiency of a Cathode, under the Conditions of Corrosion with Oxidant Depolarization.** (In Russian.) N. D. Tomashov and O. A. Deryagina. *J. Phys. Chem., USSR (Zhur. Fiz. Khim. USSR)*, 31, No. 1, 55-60 (1957).

It was shown before by Tomashov that there is a parabolical relationship between the current density at any point and the cathode area, when the rate of corrosion is determined by the diffusion rate of a depolarizer. The current density decreases with distance from the edge of the cathode. To determine the kinetics of the process Tomashov and Deryagina studied the polarization phenomena at distances of 10-2500  $\mu$  from the edge of a cathode. The limiting current in 0.02 Normal-hydrochloric acid and 0.02 Normal hydrochloric acid plus 0.24 per cent hydrogen peroxide decreased by approximately 5.6 times over a distance of 1000  $\mu$  from the edge of a cathode. The decrease is not linear. On increasing the interelectrode distance both the value of the current and the effect of the distance from the edge increases. This is explained by the change in depolarizer concentration. Minimum depolarizer concentration causes a minimum in current density. The concentration of a depolarizer at the edge of the cathode can be sufficiently high to transfer the control of the mechanism from diffusion to the reduction of the depolarizer. With cathodes sufficiently small and distances between them large, corrosion is controlled by cathodic reactions, but if inclusions are present in the cathode under the same conditions the controlling factor will be the diffusion rate.—MA. 17063

**3.7 Metallurgical Effects****3.7.3**

**Brazing-Filler Metals Meet High-Temperature Needs.** A. M. Setapen. *Iron Age*, 181, No. 19, 110-111 (1958) May 8; *Steel*, 142, No. 20, 140-142 (1958) May 19; *Industry and Welding*, 31, No. 5, 51-52, 54-55 (1958) May; *Tool Engr.*, 40, No. 6, 119-120 (1958) June.

Recent research indicates that lithium makes an important contribution to high-temperature brazing. Addition of a small percentage of the metal markedly improves fluidity and wetting ability of many standard alloys, and makes it possible to braze stainless steel in an atmosphere without flux, at temperatures as low as 1600 F. One lithium-sterling silver alloy is gaining favor for brazing honeycomb panels made of 17-7 PH stainless. Joints of sterling-lithium alloy are more corrosion resistant than those of silver-manganese. Palladium additions to silver increase melting temperature, strength and ability to wet iron and nickel base alloys. Manganese further improves wetting. For joining stainless, Inconel and other heat resisting alloys, a 70 manganese-30 nickel is being successfully used. In nickel-silicon-boron and nickel-silicon-chromium-boron group alloys, nickel is the main constituent, with silicon and boron as additions. In two of the alloys part of the nickel is replaced with chromium to provide better oxidation and corrosion resistance. Current interest in gold-nickel-chromium fillers is for lap joints between Inconel and stainless. Compared with high nickel alloys, gold alloys have lower hardness, better ductility and less tendency toward intergranular penetration. Photo.—INCO. 16649

**3.7.3**

**Welding Corrosion-Resisting Steels of the 18/8 Chromium/Nickel Type and Heat-Resisting Steels.** F. A. Ball. *Mond. Sheet Metal Inds.*, 35, Nos. 374, 375; 349-452, 509-522 (1958) June, July.

Subject is considered primarily from metallurgical viewpoint, but some de-

tails of welding procedures are given. Influence of ferrite content on weldability of stainless steels is pointed out. Methods used to determine crack sensitivity of stainless steel weld metal are discussed. Causes of weld decay and methods for overcoming it are considered, reference being made to weld decay tests and knife-line attack. Formation and properties of sigma phase are reviewed. Welding procedures discussed with reference to stainless steels are: oxyacetylene welding, atomic-hydrogen welding, metallic, argon- and submerged-arc welding and resistance welding. Tables, graphs, diagrams.—INCO. 16433

**3.7.3, 5.12, 6.2.4**

**Effect of Heat Treating on Notch Sensitivity of Chrome-Molybdenum-Vanadium Steel.** (In Russian.) Z. N. Petrovskaya. *Metalloved. I Obrabotka Metallov*, No. 7, 54-58 (1958) July. Translation available from Henry Brucher, Technical Translations, P. O. Box 157, Altadena, Calif.

Effect of heat treating on notch sensitivity of two chromium-molybdenum-vanadium steels during testing for their rupture strength. Steel compositions (1) 0.25 percent carbon, 0.35 manganese, 0.60 silicon, 2.3 chromium, 0.99 molybdenum, 0.45 vanadium; and (2) 0.33 percent carbon, 0.57 manganese, 0.68 silicon, 1.23 chromium, 0.53 molybdenum, 0.24 vanadium. Heat treatments recommended for reduced notch sensitivity and reduced embrittlement at 550 C (1020 F). 5 figures, 2 tables.—HB. 16603

**3.8 Miscellaneous Principles****3.8.2**

**Electrochemical Method for the Study of Corrosion.** (In German.) M. Pourbaix. *Schweisstechnik*, 12, 71-83 (1958) June.

Thermodynamics of corrosion of metals in aqueous solutions as well as in contact with moist substances. 9 references.—MR. 16590

**3.8.2, 3.6.8, 6.3.10**

**Local Cell Action During the Scaling of Metals.** Pt. II. Christa Ilchner-Gensch. *J. Electrochem. Soc.*, 105, No. 11, 635-638 (1958).

If nickel is covered by a borate melt under an oxygen atmosphere, practically no oxidation takes place. If, however, the nickel sample is in electrical contact with an electronic conductor, e.g., a noble metal gauze, which extends up to the melt-oxygen interface, nickel is attacked rapidly by virtue of local cell action. In this case, electron transfer is accomplished by the metal gauze and ions migrate through the borate melt. Electrochemical measurements show that the reaction is controlled mainly by polarization of the cathode where oxygen molecules are reduced to ions. 16582

**3.8.3, 6.4.2**

**Anodic Polarization of Neutral Electrolytes of Alloys of Aluminium with Alkaline Earth Elements.** A. L. Seifer. *Doklady Akad. Nauk SSSR*, 116, 120-122 (1957) September 1. (In Russian.)

The anodic polarization of high purity aluminum alloyed with calcium, strontium, and barium was studied in sea water and in 0.5N solutions of sodium chloride and sodium sulfate. The results are presented graphically.—NSA. 15408

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**3.8.3, 3.6.8, 3.2.2, 6.4.2**

**On the Anodic Polarization Behaviour of Aluminium.** P. J. Anderson and M. E. Hocking. *J. Applied Chem.*, **8**, Pt. 6, 352-358 (1958) June.

Existence of a critical potential of film breakdown, above which pitting corrosion occurs, has been established.—BTR. 16448

**3.8.3, 6.2.5**

**The Determination of Active-Passive Regions of Austenitic Stainless Steels by the Measurement of Polarization Characteristics.** Preliminary Rept. G. Okamoto, M. Nagayama, Y. Mitani and T. Ishikawa. *Corrosion Engineering (Japan)*, **7**, No. 2, 34-36 (1958) March.

Anodic polarization curves were obtained for types 304 and 316 AISI stainless in aerated sulfuric acid solutions by using the improved Hickling's potentiostat. The results, interpreted in accordance with Rocha's principle, were presented in terms of 'active/passive' regions dependent on acid concentration and temperature. The self-passivation region determined by this method was analogous to the one obtained with the usual method (i.e. the measurement of the spontaneous potential). The polarization method, however, 1) provides a more rapid mean of determining whether a specimen becomes passive or remains active under a given condition and 2) gives a better quantitative determination of the degree of stability of the specimen in the passive region.—JSPS. 16607

**3.8.4, 6.3.15**

**Demonstration of the Thixotropic Protective Layer on Metal.** (In German.) Rikuro Otsuka. *Kolloid Z.*, **153**, 59 (1957) July.

The formation of a thixotropic protective layer on pure titanium (99.3% by weight) was demonstrated by an experiment in which titanium sheet metal electrodes were immersed in 0.10 N aqueous potassium chloride. Simultaneous pitting and the formation of white, colloidal titanium oxide hydrate are observed on the application of 12 volts at the electrodes. 3 references.—MR. 14850

**3.8.4, 6.4.2**

**Structure of Non-Porous Anodic Films on Aluminium.** R. W. Franklin. *Nature*, **180**, No. 4600, 1470-1471 (1957) December 28.

By means of optical and electron microscopy and by preferential chemical dissolution, it has been found that non-porous oxide films formed on aluminum by anodic oxidation and aqueous electrolytes are not uniform in thickness and composition. The non-porous oxide films formed when aluminum is polarized anodically at either constant current or constant voltage in a variety of aqueous electrolytes (for example, borates, carbonates, tartrates and phosphates) at room temperature have a pronounced cell type of structure. The surface at both electrolyte-oxide and metal-oxide interfaces is covered with raised domes. The average radius of the cells is proportional to the voltage and is approximately equal to the average thickness of the oxide. As the whole surface is covered with cells, the number of cells must decrease as the formation voltage increases. The number and size of the cells appear to be independent of the grain orientation of the underlying metal. As the thickness of the anodic film is not uniform, it must be easier for the oxide to grow at some points of the film than at others. This

indicates that the layer may not be of uniform composition and this has been confirmed. If anodic aluminum films are treated with a hot chromic acid-phosphoric acid solution, part of the oxide dissolves rapidly and part is insoluble. It has been found that the soluble portion occurs in a central column through cells and the insoluble in the region of the junction between the cells. The insoluble material gives sharp electron diffraction patterns and appears to be crystalline  $\gamma'$  aluminum and it is believed that the soluble portion is practically amorphous. As the temperature of formation is increased, the amount of insoluble crystalline oxide increases considerably. It is apparent that this type of construction of the oxide layer can explain the growth of porous films on aluminum.—ALL. 15228

**6. MATERIALS OF CONSTRUCTION****6.2 Ferrous Metals and Alloys****6.2.5, 4.3.6, 3.5.9, 3.2.2**

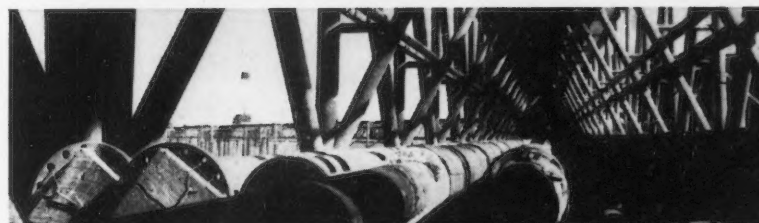
**Corrosion of Types 347 and 309 SCB Stainless Steels by Simulated "25" Process Waste Solutions at Various Temperatures.** Arnold R. Olsen. Oak Ridge National Lab. U. S. Atomic Energy Commission Pubn., CF-54-6-7, June 1, 1954 (Declassified Feb. 14, 1957), 40 pp. Available from Office of Technical Services, Washington, D. C.

Corrosion tests on stainless steels Type 347 and Type 309 SCB exposed to concentrated simulated first cycle raffi-

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nate (predominantly 2.5 molar aluminum nitrate) from "25" Process at Arco at temperatures from 120 F to boiling have been made. The corrosion rates are distinctly temperature dependent. Severe intergranular attack occurred at temperatures above 180 F disappearing at 150 F for Type 347 stainless steel and at 120 F for Type 309 SCb stainless steel. From the results of these tests it appears that successful long time storage of this waste will require that the solution temperature be maintained below 150 F. (auth)—NSA. 16993

#### 6.2.5, 6.2.2, 1.3

**Materials of Construction—Stainless Steels and Other Ferrous Alloys.** W. A. Luce and J. H. Peacock. Duriron Co. Ind. Eng. Chem., 50, No. 9, Pt. 2, 1482-1488 (1958) Sept.

Annual review of published literature with 137 references covers corrosion, mechanical properties, structure, high temperature properties and applications, welding, manufacture and surface treatment of stainless steels. Survey of literature on high-silicon iron, nickel irons and austenitic iron-manganese steels is included.—INCO. 17472

#### 6.2.5, 8.8.5, 3.7.2

**The Effect of Boron on Liquid-Phase Formation in Sintered Steels, Particularly Steels with About 18% Chromium and 8% Nickel.** (In German.) Friedrich Benesovsky and Werner Hotop. Stahl und Eisen, 78, No. 3, 149-152 (1958).

A low m.p. nickel-chromium-boron alloy was added to the powders from which sintered steels were made, and the structure and properties after sintering were examined. Up to 2-per cent addition to 18:8 chromium-nickel steel raises the strength, hardness and improves the ductility. The alloys so produced are resistant to corrosion and scaling.—MA. 17168

#### 6.2.5, 8.9.1

**Sheet Steels for High-Speed Aircraft and Missiles.** A. L. Feild and M. E. Carruthers. Armco Steel Corp. Aero/Space Eng., 17, No. 6, 41-44 (1958) June.

Some of the steels used in manned aircraft and missiles may be classified as being of the martensitic type. Others are stainless steels that strengthen through a change in phase and a secondary hardening mechanism "t" termed precipitation hardening. Still others are austenitic steels strengthened by precipitation hardening. Among the high strength steels available today, only the precipitation hardening stainless steels have satisfied production honeycomb requirements. Strength-weight comparisons are given for 6Al-4V, Type 422M, PH 15-7 and A286 alloys. Austenitic stainless steels, such as A286, are the most corrosion resistant, but they are not competitive strengthwise with other steels at temperatures below 1000 F. Of the high strength sheet steels used in aircraft and missiles, the PH 17-7 stainless steel has been most widely used and produced in the greatest tonnage. Because of its higher strength at room and elevated temperatures, the PH 15-7 molybdenum stainless steel is being designed into many of the advanced weapons systems. Superior resistance to corrosion and better feasibility of production of aircraft parts also account for its acceptance in preference to the stronger hot work die steels and martensitic stainless. Graphs, tables.—INCO. 17089

## 6.3 Non-Ferrous Metals and Alloys—Heavy

#### 6.3.10, 3.7.4

**Investigation of the Alloys of the Ternary System Nickel-Aluminum-Tungsten.** (In Russian.) P. B. Budberg. Zhur. Neorg. Khim., 3, 694-698 (1958) March.

Investigation on alloys of ternary system nickel-aluminum-tungsten with up to 30 aluminum and up to 40 tungsten. By the method of thermal analysis, a part of the freezing curve of the binary system NiAl-W was determined and the eutectic character of the relationship between that curve and the formation of the limited solid solution of tungsten in NiAl was demonstrated. Phase-region boundaries in the investigated part of the system were determined at different temperatures by microstructure studies. Isothermal sections of the system at 1200, 1000 and 800 C were constructed.—INCO. 17286

#### 6.3.10, 3.7.4, 3.7.2

**Superstructure and K-State in the Nickel-Chromium System.** (In German.) H. G. Baer. Z. Metallkunde, 49, No. 12, 614-622 (1958) Dec.

Superstructure Ni<sub>3</sub>Cr has been detected in nickel-chromium system. It is associated with a decrease in resistance and change in Hall constant. It exists at approximately 25-36 at-per cent chromium. Critical ordering temperature is 580 C for alloy with 33.7 at-per cent chromium. Upon cooling, transformation occurs just below 500 C. Order is destroyed by cold working. Resistivity increases. On the other hand, for alloys with lower chromium content, which form K-state, resistivity decreases. Solubility curve for chromium has been determined. Tables, graphs.—INCO. 17166

#### 6.3.10, 4.7

**Depletion of Minor Constituents from Coast Metals No. 52 (89 Ni-5 Si-4 B-2Fe) and No. 53 (81 Ni-8 Cr-4 B-3 Fe) Brazing Alloys During Various Exposures.** D. H. Jansen. Oak Ridge National Lab. U. S. Atomic Energy Commission Publ., CF-58-10-86, October 23, 1958, 15 pp. Available from Office of Technical Services, Washington, D. C.

Corrosion tests were made on nickel-base brazing alloys containing boron and silicon in fused fluoride fuels, liquid metals and oxidizing atmospheres. Impoverished regions, after the tests, contained approximately one third the original amount of boron and silicon that was present before the tests.—NSA. 17380

#### 6.3.10, 5.3.4

**What Electroless Nickel Can Do for You.** R. J. Girard. Paper before Am. Electroplaters' Soc., Springfield Branch, Jan. 1958. Plating, 45, No. 12, 1234-1238 (1958) Dec.

Physical properties of electroless nickel considered considered include: structure, appearance, corrosion resistance, buffability, hardness, composition, ductility, receptiveness and porosity. Plating tanks, ventilation, preparation of plating solutions, racking of components, deposition of nickel, operating conditions and their control (temperature, pH, agitation) and filtration are reviewed. Cycle of operation is outlined. Limitations, advantages and economic appraisal are considered. Table compares hardness, elongation and tensile strength of electroless nickel with other types of nickel deposits.—INCO. 17403



## 6.3.11, 3.4.6, 3.5.9

**The Solid-State Reactions of the Noble Metals and Their Alloys with Oxygen at Elevated Temperatures.** (In German.) Ernst Raub and Werner Plate. *Z. Metallkunde*, 48, No. 10, 529-537 (1957).

Silver, gold, palladium, platinum and rhodium and their alloys in the series silver-gold, palladium-silver, platinum-gold, platinum-rhodium, and platinum-iridium were heated at 900-1300 C (always below the melting point of the material) in a current of oxygen, in air, and in oxygen-containing nitrogen, and studies were made of their changes in weight in relation to temperature and time of heating, and the influence of oxygen on the surface structure. An initial weight gain results from oxide formation; these oxides then volatilize with increasing time and/or temperature, and the weight loss is approximately linear with time. Gold does not appear to react with oxygen. Silver volatilizes appreciably at 600 C; trace impurities in the metal oxidize and then volatilize. Platinum volatilizes faster than palladium and rhodium at 900-1100 C, but at 1300 C this difference vanishes; alloying of platinum with palladium and rhodium reduce volatilization, while alloying with iridium increases it; gold up to 75 per cent has little effect, probably owing to the wide miscibility gap in the platinum-gold system. Gold and platinum reduce the volatilization of silver. At high temperature, palladium and rhodium dissolve considerable amounts of oxygen; at 1200 C  $> 0.4$  at. per cent oxygen is soluble in palladium. The thermal etching of these materials is illustrated and discussed. 17 references.—MA. 17064

## 6.3.11, 7.7

**The Care of Platinum Thermocouples.** H. E. Bennett. *Platinum Metals Rev.*, 2, No. 4, 120-123 (1958) October.

Platinum and its alloys will withstand much more adverse conditions than will base metal thermocouples, but they none the less have their limitations. Melting point of platinum is 1769 C and that of its highest melting rhodium alloy is about 1890 C. Harmful effects of prolonged heating, contamination by metallic vapors and embrittlement due to oil and grease are discussed. Results of creep tests on platinum-rhodium thermocouples are given. Photomicrographs, graphs.—INCO. 17158

## 6.3.15, 1.6

**Symposium on Titanium.** Am. Soc. for Testing Materials. Presented at the Second Pacific Area National Meeting of the Society Held at Los Angeles, Calif. on 17-18 September 1956. A.S.T.M. Special Technical Publ. No. 204, 208 pp., 1958. Available from the Society, 1916 Race Street, Philadelphia 3, Penn.

Contents: F. R. Schwartzberg, N. D. Williams and R. I. Jaffee, Variables Affecting the Thermal Stability of Three Titanium Alloys; F. C. Holden, H. R. Ogden and R. I. Jaffee, The effect of Temperature on the Uniform Elongation of Titanium Alloys; H. R. Ogden, F. C. Holden and R. I. Jaffee, The Effect of Composition and Annealing Treatment on the Thermal Stability of Chromium-Molybdenum Alloys of Titanium; W. M. Parris, R. G. Sherman and H. D. Kessler, Elevated-Temperature Properties of the 6 per cent Aluminum-4 per cent Vanadium-Titanium Alloy;

F. A. Crossley, W. F. Carew and H. D. Kessler, Development of Titanium-Base Alloys for Elevated-Temperature Application; E. P. Klier and N. J. Feola, The Effects of Carbon and Nitrogen Contamination on the Notch-Tensile Properties of Titanium; F. C. Holden, H. R. Ogden and R. I. Jaffee, A Micro-Notched-Bar Impact Test for Titanium Alloys; W. H. Graft and W. Rostoker, The Measurement of Elastic Modulus of Titanium Alloys; J. B. Rittenhouse, The Corrosion and Ignition of Titanium in Fuming Nitric Acid; H. H. Barry and L. Schapiro, Unalloyed Titanium Sheet is Improving; Chester R. Smith, How Statistical Techniques Helped Achieve Better Uniformity in Unalloy Titanium; L. B. Stark, Properties and Fabrication Characteristics of Wrought Titanium

Products; R. L. Folkman and M. Schussler, Development of Standardized Specimen Preparation and Testing Techniques for Unalloyed Titanium Sheet; R. M. Fowler, Determination of Gaseous Elements in Titanium.—MA. 17283

## 6.3.15, 3.4.8

**Corrosion of Titanium by Chloride and Sulfate Anions, Revealed by Electrode Potential Measurements.** (In English.) E. M. Khairy and M. M. El-Khatib. *Egyptian Journal of Chemistry*, 1, No. 2, 263-285 (1958).

Experiments with spectroscopically pure titanium rods in buffered and unbuffered hydrochloric acid-sodium chloride and sulfuric acid-sodium sulfate solutions. The corrosion is explained by

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the action of chlorine-ions or sulfate-ions, respectively. 11 references.—RML. 17368

#### 6.3.15, 3.4.8, 3.2.2

**Utilization of Low-Grade Titanium Sponge Produced by the Kroll Process. Pt. 3. Corrosion of Titanium-Iron Alloys in Hydrogen Sulfide Atmosphere at High Temperature.** (In Japanese.) K. Hirayama, N. Gamo and T. Takei. Sci. Res. Inst., Tokyo, Repts., 33, 228-233 (1957) July.

Corrosion resistance was not influenced by iron content, and was far superior to that of 18-8 stainless steel. Appreciable corrosive attack by hydrogen sulfide was observed at 600°C and above. A relatively compact film of metallic sulfide was formed during the corrosion process and the process was controlled by mutual diffusion of metallic and gaseous ions through the sulfide film. Corrosion rendered the alloys somewhat brittle, the degree of brittleness being proportional to the time and temperature. This embrittlement is attributed to the absorption of hydrogen. 7 references.—MR. 17139

#### 6.3.20

**Second Interim Report on the Zircaloy Alloy Corrosion Problem.** J. G. Goodwin. Westinghouse Electric Corp. U. S. Atomic Energy Commission Pubn., WAPD-NCE-4512, May 1, 1957, 32 pp. Available from Office of Technical Services, Washington, D. C.

The Zircaloy-3 corrosion problem is associated with white or tan stringers found in the black matrix oxide of Zircaloy-3 samples corrosion tested for 14 days in 750°F steam. The stringers are parallel to the direction of rolling. A similar effect is noted in the cladding of corrosion tested fuel elements manufactured from strip showing this behavior. Because the stringers are noted in the fuel elements and could lead to possible difficulties, an investigation was begun to determine the reasons for the stringers and to determine methods for eliminating them. (auth).—NSA. 16183

## 8. INDUSTRIES

### 8.4 Group 4

#### 8.4.5, 4.3.3, 3.2.2

**Additional Considerations on the Use of Lithium Hydroxide in PWR.** J. C. Rengel. Westinghouse Electric Corp. U. S. Atomic Energy Commission Pubn., WAPD-PWR-PFM-868, August 29,

1957, 8 pp. Available from Office of Technical Services, Washington, D. C. Lithium hydroxide was recommended as the reference condition for the Pressurized Water Reactor coolant. An investigation of the possibility of caustic stress-corrosion cracking arising from the use of lithium hydroxide is presented.—NSA. 17050

#### 8.4.5, 4.6.1

**The Inter-Relation of Loop or Reactor System Transport and Dynamic Corrosion in Water.** C. G. Lindquist. Knolls Atomic Power Lab. U. S. Atomic Energy Commission Pubn., KAPL-M-CGL-1, Sept. 12, 1958, 12 pp. Available from Office of Technical Services, Washington, D. C.

The conditions in which the flow of fluid past a corroding surface could affect the corrosion rate are outlined, and the formulation of these factors is discussed. In addition, an analysis of transport in dynamic corrosion loop systems is presented.—NSA. 17442

#### 8.4.5, 4.6.1, 3.5.4, 6.3.20, 3.2.2

**Metallurgy in Nuclear Engineering. Survey of the Literature in 1957.** J. Burkett. Metallurgia, 58, No. 345, 32-35 (1958) July.

Discussion of stress corrosion cracking problems of materials in homogeneous reactor tests include results of corrosion runs on titanium, zirconium 2 and stainless steel. Corrosion of alloys over range 240-360°C in high temperature water was studied. Armco 17-4PH, Armco 17-7PH and Hastelloy F alloys were the most resistant materials at 730 and 540°C. AISI 316 was susceptible to stress corrosion cracking at 730°C. Carbon steel, carbon steel weldments, nickel steel, high-strength steel and high-purity iron were irradiated in the MTR. Neutron irradiation increases yield and tensile strengths of structural steels but decreases their ductility, possibly changing behavior of steels as materials for structural components. Zirconium as a reactor material is discussed.—INCO. 17297

#### 8.4.5, 4.6.1, 3.5.8, 6.2.5

**Stress-Corrosion Failure of a High-Pressure Water/Water Cooler in the Dynamic Corrosion Loop at Capenhurst.** G. E. Marchment. United Kingdom Atomic Energy Authority, July 14, 1958, 14 pp. Available from: United Kingdom Atomic Energy Authority, Industrial Group, Capenhurst Works, Capenhurst, Ches., England. (IGR-TN/CA-974).

Failure occurred in a stainless steel water/water cooler, of the shell-and-coil type, used to cool a water flow from 300 to 40°C in the dynamic corrosion loop. The failure is attributed to stress corrosion in the presence of dissolved chlorides, which occurred in areas where steam is likely to be forming continuously. Although the best long-term solution is to introduce a regenerative heat exchanger to reduce the temperature of the inlet water, an amended design of cooler is suggested for immediate use in the loop. (auth).—NSA. 17494

#### 8.4.5, 4.6.2

**Effect of In-Pile Local Boiling on Surface Deposition and Corrosion.** Kurt Katz and Walter E. Hopkins, Jr. Westinghouse Electric Corp., Pittsburgh. Nuclear Sci. and Eng., 4, No. 5, 673-689 (1958) Nov.

Many advantages can be realized by operating a pressurized water reactor at

steady-state local boiling conditions. However, before this mode of operation can be factored into the thermal and hydraulics of reactor design, its effect on cladding corrosion and surface crud deposition must be established. The evaluation of a local boiling test at pH 7, for crud deposition and corrosion is described. (auth).—NSA. 17355

#### 8.4.5, 8.9.5

**The Power Plant for the First Nuclear Merchant Ship N. S. Savannah.** J. W. Landis. Paper before Nuclear Merchant Ship Symposium, Washington, D. C., Aug. 21, 1958. J. Am. Soc. Naval Engrs., 70, No. 11, 629-641 (1958) Nov.

Detailed description of nuclear reactor for N. S. Savannah. Reactor is pressurized water reactor operating at 1750 psia and fueled with uranium dioxide of about 4 per cent enrichment clad in boron-containing Type 304. Control rods are of composite design with plate of boron-containing stainless steel sandwiched between 2 ordinary stainless steel plates. Rod spacing is maintained by small tubular stainless steel ferrules brazed in place. Pressure vessel is made of 6 in. carbon steel plate clad on inside with Type 304. Inconel X is used for fuel element springs. Steam generators each consist of uranium-shell, uranium-tube boiler section containing about 800 stainless steel tubes ¾ O.D. All primary piping is made from Type 304 hollow forgings. Numerous diagrams.—INCO. 17439

#### 8.4.5, 8.10.2, 6.4.2

**The Preparation and Reprocessing of Plutonium-Aluminum Alloy.** W. L. Lyon. General Electric Co., Hanford Atomic Products Operation, U. S. Atomic Energy Commission Pubn., A/CONF.15/P/546, 7 pp. Prepared for the second U. N. International Conference on the Peaceful Uses of Atomic Energy, 1958. Available from Office of Technical Services, Washington, D. C.

An alloy of plutonium and aluminum offers an attractive reactor fuel material since the technology of the matrix is sound, the alloy is readily produced and fabricated, it has good nuclear and physical properties, and it is acceptable with water coolant as regards heat transfer and corrosion rate. The alloy may be produced by direct alloying of the metals, or by reduction of plutonium fluoride or oxide in aluminum. The latter method, wherein PuO<sub>2</sub> and cryolite mixtures are added to molten aluminum, employing the technique of Saller and Runnalls, is expected to find extensive application in the production of fuel loadings for power reactors. The chemical reprocessing of plutonium-aluminum fuel may be accomplished by adapting aqueous methods for which sound technical bases exist. On the other hand, this material may lend itself to processing by one of several interesting pyrochemical schemes. Some of these are described together with brief comments regarding the economics of plutonium fuel processing. (auth).—NSA. 17459

### 8.8 Group 8

#### 8.8.5, 6.2.2

**Experimental Study of Electric Furnace Refining of Magnesium Treated Cast Iron Under Reducing Atmosphere.** (In Japanese.) M. Homma, H. Meguro, Y. Abe and R. Ono. J. Japan Foundrymen's Soc., 30, No. 8, 597-602 (1958) August.

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In manufacturing magnesium treated nodular cast iron, the effect of reduction-refining with acid or basic electric arc furnace on its properties was investigated. Strong desulfurizing and deoxidizing actions were observed. The necessary amount of magnesium for manufacturing ductile iron with cupola is about 0.4 per cent, but the magnesium amount could be reduced to 0.11-0.17 per cent with basic furnaces and with acid furnaces to 0.18-0.23 per cent. Both dross and depth of shrinkage cavity in the ingots were reduced by reduction refining with electric furnace. The test piece for mechanical property was taken from Type JIS No. 4 iron which was cast into green sand mold and annealed to such extent as ferrite structure revealed. Tensile strength, yield point and elongation obtained from specimens from basic and acid processes are given. Sulfur content of the original material was 0.024-0.031 per cent. It was however desulfurized in the basic furnace by 65-96 percent retaining sulfur content only between 0.001 and 0.010 per cent, while in the acid furnace only 63-89 per cent of the above content was desulfurized retaining it between 0.03 and 0.011 per cent.—INCO. 17371

#### 8.8.5, 6.2.2, 3.7.2

**Gray Iron Chemistry—How It Affects Casting Quality.** F. L. Arnold, Carver Foundry Inc. Foundry, 86, No. 12, 86-89 (1958) Dec.

Reviews influence of carbon, silicon, sulfur, manganese and phosphorus contents on quality of castings, and defines significance of carbon equivalent. Some of most common casting defects—shrinkage, internal porosity, hot tearing and mis-runs—caused by wrong metal analysis, are discussed. Avoiding hard surfaces in thin sections, and control of fluidity are considered.—INCO. 17170

#### 8.8.5, 6.3.10

**Some High-Temperature Properties of Nickel-Alloy Powder. Extrusions Containing Nonmetallic Dispersions.** E. Gregory and C. G. Goetzel, Trans. Met. Soc. AIME (Am. Inst. Mining & Met. Engrs.), 212, No. 6, 868-874 (1958) Dec.

Experimental powder-metallurgy materials made by extrusion consist of 80-20 nickel-chromium alloy matrices with various hard-phase additions. Several methods of obtaining a uniform dispersion of a hard phase throughout a ductile metal matrix are reviewed, although the mechanical mixing method is the principal one employed. Stress-rupture tests on the extruded materials were carried out at both 1500 and 1800 F and showed that high-temperature strength of matrix could be increased considerably with certain oxide and carbide additions. High temperature ductility and room-temperature impact values of some of these materials were low in comparison with cast and wrought alloys. Optical and electron microscopical examinations revealed variations in structure which resulted from changes in conditions and methods of manufacture. Photomicrographs, graphs.—INCO. 17401

#### 8.8.5, 6.3.17

**Arc-Melting of Uranium-Rich Alloys.** W. H. Britton and W. B. Haynes, Nuclear Metallurgy, 4, 63-66 (1957).

The technique has been limited to experimental metal of small ingots and as a pre-alloying melt to precede vacuum-induction-melting. Consumable-electrode arc-melting of uranium-molybdenum al-

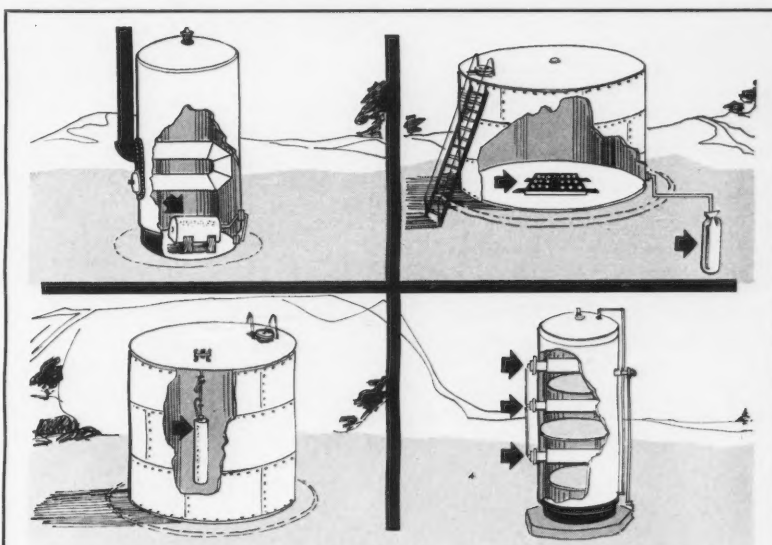
loys in an argon-helium atmosphere yields sound, homogeneous ingots, but of uranium-niobium is more difficult, since the wider solidification range leads to microsegregation associated with poor aqueous corrosion-resistance.—MA. 17034

#### 8.8.5, 6.4.1

**Economic Design of Light-Alloy Castings.** P. A. Broadbent, Foundry Trade J., 105, No. 2201, 737-744 (1958) Dec. 18.

Light alloy castings can already be produced to consistently close limits by well-established die-casting methods, so the post-war developments of precision moulds are of more benefit to the other non-ferrous and ferrous foundry industries. Furthermore, the special light alloy foundry techniques, the heat treatment and other processes, and the free-cutting properties of light alloys

should be related to design and costs of production. Test-bar specifications for a number of aluminum and magnesium alloys are given and are discussed in relation to strength and weight of castings, to certain features of design and to the cost of a machined casting in cast iron and various light alloys. High tensile steel bolts are necessary to shear screw threads in light alloys and results of tensile tests on inserts and fastenings are given, together with estimates of cost of each method of assembly. Where inserts and fastenings are used, precautions to avoid galvanic action between dissimilar metals are necessary only on exposed junctions, while for corrosion generally, precautions are just as necessary for the common light alloys as for the common iron and steel constructional materials and components. (auth) —ALL. 17189



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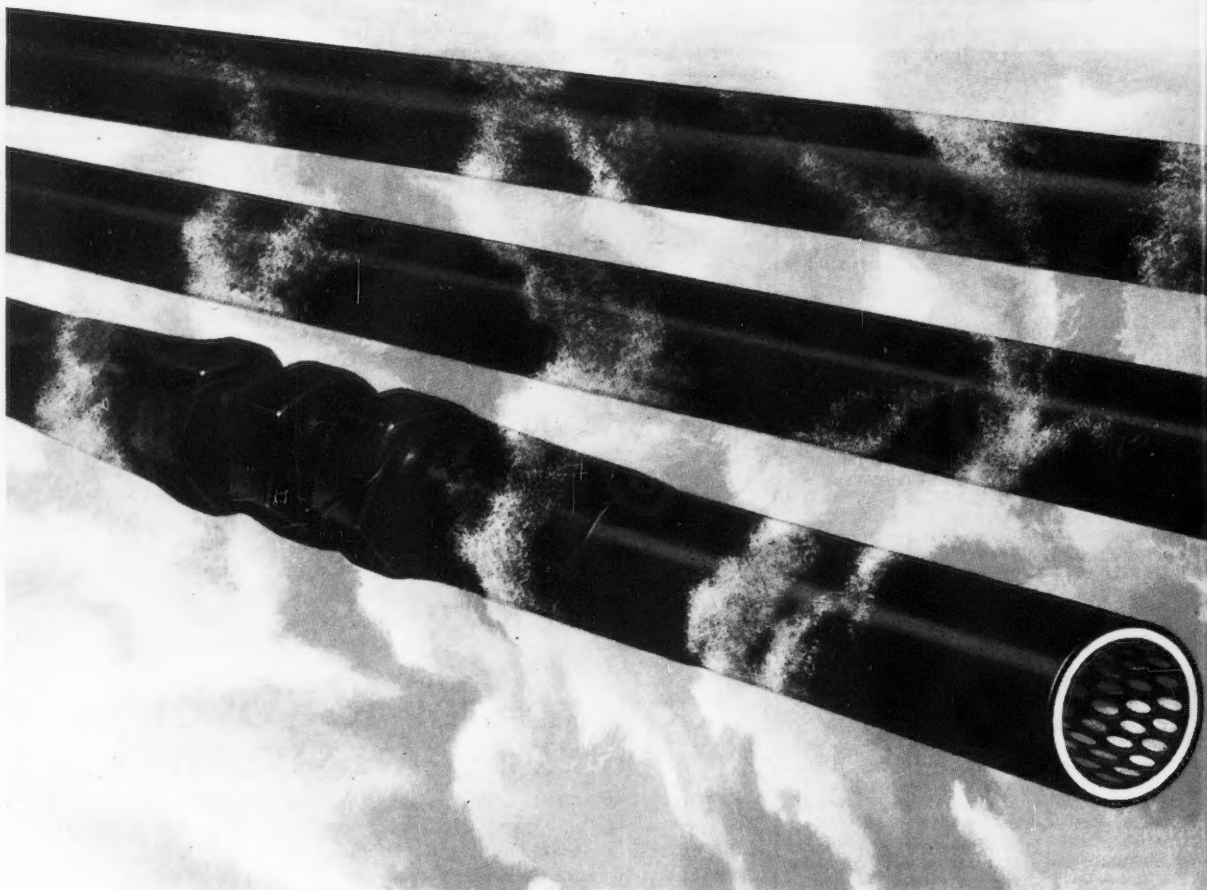
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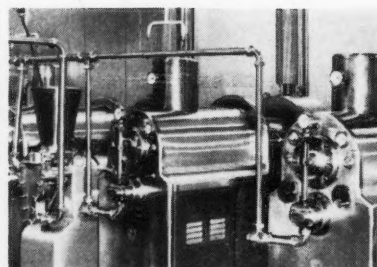
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# INDEX TO ADVERTISERS

Vol. 15

December, 1959

No. 12

	Page		Page
Amchem Products, Inc.	4	Koppers Company, Inc.	
Amercoat Corporation	Inside Front Cover	Tar Products Division	95
American Cyanamid Co., Plastics and Resins Div.	89	Kraloy Plastic Pipe Co., Inc.	7
Bridgeport Brass Company	5	Mayes Brothers, Inc.	82
Byers, A. M. Company Wrought Iron	87	Minnesota Mining & Manufacturing Co.	9
Calgon Company, Division of Hagan Chemicals and Controls, Inc.	11	National Association of Corrosion Engineers	10, 75, 81, 114
Carboline Company	92	National Carbon Company Division of Union Carbide Corporation	77
Carey Manufacturing Co., The Philip	107	Pittsburgh Coke and Chemical Co.	Back Cover
Cathodic Protection Service	105	Polyken Products, Dept. of The Kendall Company	70, 71
Corrosion Engineering Directory	90	Positions Wanted and Available	88
Corrosion Rectifying Company	112	Prufcoat Laboratories, Inc.	97
Corrosion Services, Inc.	117	Reilly Tar & Chemical Corporation	113
DeVilbiss Company, The	83	Republic Steel Corporation	118, 119
Dowell	1	Royston Laboratories, Inc.	108
Duriron Company, The	Inside Back Cover	Solvay Process Division Allied Chemical Corporation	103
Farley-Bosch Company	96	Standard Magnesium Corporation	106
Gates Engineering Company	79	Standard Pipeprotection, Inc.	91
Good-All Electric Manufacturing Co.	110	Tapcoat Co., The	85
Hommel Company, The O.	86	Tretolite Company	101
Humble Oil and Refining Company	98	Tube-Kote, Inc.	80
International Nickel Co., Inc. The	73	Wholesale Coke Company	116
International Paint Company, Inc.	115	Wisconsin Protective Coating Co.	102
Johns-Manville Corporation Plumbing Vent Pipe	111		

## 8.10.2, 6.3.17, 6.3.21, 6.7.2

**Powder Metallurgy of Uranium and Thorium.** A. Blainey. *Metal Progress*, 74, No. 2, 79-85 (1958) August.

Presents brief summary of recent British work on powder metallurgy of uranium and thorium. Uranium powder is produced by direct reduction of urania with calcium or magnesium. Calcium-reduced uranium powder was extruded into 1/4-in rods through Stellite or cemented titanium carbide dies at 800 C. Stellite was sometimes attacked by erosive action of gamma uranium, titanium carbide was liable to fracture. Troubles were corrective by using Nimonic-80 or 90 dies coated with 0.005-in. layer of zirconium alloy. Technique developed for hot compacting long bars from cold compacted pellets of waxed powders utilizes opposing plungers in Stellite split tapered sleeve die and electrically heated Nimonic-80 bolster. Fabrication of ceramic fuels is reviewed. Nickel, iron, cobalt and uranium binders were explored during fabrication of UC cermets. Nickel and iron may find application in fast reactors.—INCO. 17319

## 8.10.2, 6.3.10

**Recovery of Nickel from Converter Mattes.** (In Russian.) L. L. Chermak. *Tsvetnyye Metal. (Non-Ferrous Metals)*, No. 9, 37-39 (1958).

Author has attempted to determine activity of nickel and sulfur in sulfide fusions by measuring electromotive

force, using an amalgam type cell. Electrodes of cell, body of which was manufactured from high-quality chamotte, are sulfide fusions of nickel; electrolyte is liquid mixture of potassium and nickel chlorides (potassium chloride replaced by more volatile barium chloride above 1000 C). Fusions, saturated with nickel, served as comparison solutions in each of tests. Conducted investigation showed that in transition from standard fusions to one with high sulfur contents, coefficient of nickel activity is reduced by 10 times and coefficient of sulfur activity grows by 100 times. Behavior of nickel and sulfur is characterized by very high deviations from ideal solutions. Table gives data obtained for 1200 C. A quantitative relationship is established between sulfur content in converter matte and temperature of finishing process. Advisability of obtaining nickel and copper-nickel converter mattes with increased sulfur contents is indicated. Presented data show that it is sufficient to lower temperature at which finishing of converter matte is carried out, to 1000-1050 C.—INCO. 17209

## 8.10.2, 3.5.9

**High-Temperature Metallurgy Today.** L. P. Jahnke and R. G. Frank. *Gen. Elec. Co. Metal Progress*, 74, Nos. 5, 6; 77-82; 86-91 (1958) Nov., Dec.

Mechanisms for strengthening alloys (dislocation pinning by solute atoms, by short-range order, by cold work and by

2nd phase particles) which have resulted in improved elevated-temperature materials are reviewed. These considerations are carried into discussion of development of improved superalloys and refractory metal compositions. Properties of some of the best superalloys (A-286, M-308, D-979, Unitemp 212, René 41, DCM, L-605, V-36, etc.) are presented, and future performance of refractory metal alloys predicted. Best alloys among light metals (aluminum, magnesium and titanium) and steels (Halmco, Potomac M, VascoJet 1000, AM 355, PH 15-7 Mo, 17-7 PH, Lapelloy) are reviewed. Until oxidation problem is solved or by-passed, nickel alloys will dominate applications in 1000-2000 F range. On basis of strength-to-weight ratios: aluminum becomes slightly more attractive up to 500 F; titanium is generally competitive at low temperatures with semi-austenitic stainless steels; nickel-base alloys are still best above 1000 F and molybdenum dominates applications above 1600 F despite its higher density; and niobium has crept up on molybdenum and unalloyed tungsten has fallen below niobium. Numerous tables and graphs.—INCO. 17385

## 8.10.2

**Iron and Nickel by Carbonyl Treatment.** R. M. Lewis, J. W. Cookston, L. W. Coffer and F. M. Stephens, Jr. *J. Metals*, 10, No. 6, 419-424 (1958) June.

Recovery of nickel and iron from lateritic nickeliferous ores by formation and decomposition of their carbonyls. Thermodynamic studies of reactions involving nickel and carbon monoxide and iron and carbon monoxide are summarized. Experimental work on carbonyl treatment was performed on samples of several different ores, including an analysis similar to material now being treated at the Nicaro plant using ammonia leach process. It was found that 95 nickel and 90 iron could be reduced with 10 times stoichiometric quantity of hydrogen in 2-hr treatment at 700 C. When treated with carbon monoxide under pressure of 375 psig at 100 C, up to 69 nickel and 62 iron were converted to carbonyls. In subsequent treatments mixtures of ammonia and carbon monoxide were used, as addition of ammonia inhibited catalytic decomposition of carbon monoxide and eliminated slagging condition. Effects of temperature and ore characteristics and considered. To eliminate adverse effect of adsorbed films of carbonyls on ore, —65 mesh ore was slurried with mixed iron and nickel carbonyls, slurry was stirred in autoclave under carbon monoxide pressure of 375 psig and temperature of 100 C for 16 hrs. Conversions of 65 nickel and iron were obtained. Both wet (slurry) treatment and dry treatment were used to investigate effects of temperature and pressure on carbonyl formation reactions. Separation of carbonyls by distillation is discussed. Nickel carbonyl was decomposed at 200-260 C under pressures of 30-760 mm mercury, while iron carbonyl was decomposed at 250-300 C under pressures of 30 mm to 150 psig. All steps leading to production of nickel and iron metals by wet carbonyl process were technically feasible in small-scale batch operations; integration of system into semicontinuous operation was successful. Tables, flow-sheet, equipment diagrams.—INCO. 16942



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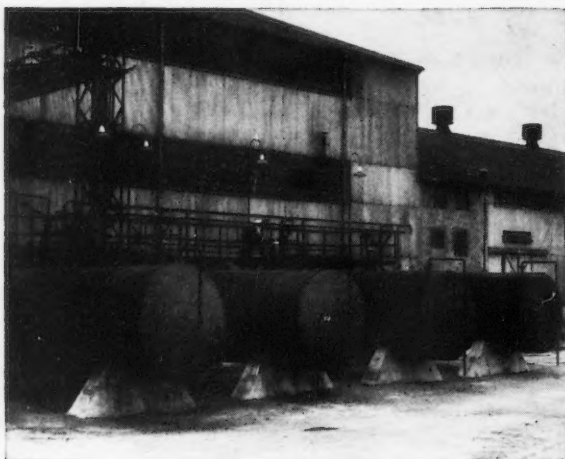


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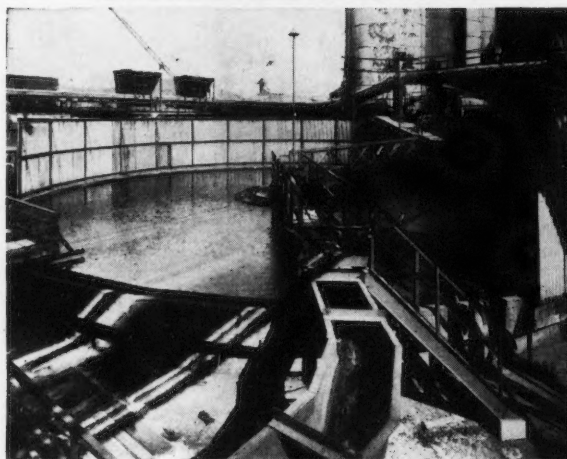
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INDEX TO TECHNICAL AND TECHNICAL TOPICS  
SECTIONS

# CORROSION

## VOLUME 15

JANUARY 1—DECEMBER 31

1959

## C O N T E N T S

Tables of Contents

Alphabetical Subject Index

Alphabetical Index to Authors

## PAGE NUMBERS BY MONTHS

Pages		Pages	
1t- 48t	January	239t-394t	July
49t-100t	February	395t-446t	August
101t-166t	March	447t-502t	September
167t-220t	April	503t-556t	October
221t-282t	May	557t-618t	November
283t-338t	June	619t-646t	December



# Tables of Contents

## CORROSION Technical and Technical Topics Sections, Volume 15, 1959

January	Page	February—Continued	Page	April—Continued	Page
Topic of the Month—Corrosion of Valve Seat Ring Results in Flexible Metal by J. E. Prior.....	1t	Developments in Cooling Tower System Treatments (Part 1—Polyvalent Ion-Polyphosphate Inhibitors) by J. I. Bregman and T. R. Newman.....	97t	Oil Refinery Applications of Thick-Film Synthetic Coatings by R. W. Maier, W. B. Cook and R. B. MacQueen.....	171t
Corrosion of Steel Weldments by J. U. MacEwan and H. H. Yates.....	2t	<b>Technical Topics</b>		Corrosion Rate Measurement by Hydrogen Effusion in Dynamic Aqueous Systems at Elevated Temperature and Pressure by M. Krulfeld, M. C. Bloom and R. E. Seebold.....	179t
High Temperature Corrosion Product Films on Aluminum by V. H. Troutner.....	7t	Cathodic Protection for Naval Vessels—Experimental Studies by L. J. Waldron, M. H. Peterson and M. C. Bloom.....	87	Visual Observations on the Water Stream in an Elevated Temperature High Velocity Loop by R. E. Seebold.....	183t
Observations on the Mechanisms and Kinetics of Aqueous Aluminum Corrosion (Part 1—Role of the Corrosion Product Film in the Uniform Aqueous Corrosion of Aluminum) by V. H. Troutner.....	9t	Advantages of Reinforced Polyesters for Use on Highway Tank Trucks by James M. Brady.....	94	Minimum Corrosion for Butane Isomerization Units—A Contribution to the Work of NACE Group Committee T-8 on Refining Industry Corrosion by J. F. Mason, Jr., and C. M. Schillmoller. Publication 59-11.....	185t
Discussion: Page 642t		Applications of Lead-Acid Brick Systems in Chemical Plants by E. J. Mullarkey.....	98	<b>Technical Topics</b>	
Observations on the Mechanisms and Kinetics of Aqueous Aluminum Corrosion (Part 2—Kinetics of Aqueous Aluminum Corrosion) by R. L. Dillon.....	13t	<b>March</b>	<b>Page</b>	Corrosion of Refinery Equipment by Aqueous Hydrogen Sulfide—A Contribution to the Work of NACE Group Committee T-8 on Refining Industry Corrosion by Roy W. Comeaux. Publication 59-12.....	189t
Discussion: Page 642t		Equipment and Procedure for Evaluation of Stress Corrosion Susceptibility of a Wrought Copper Base Alloy by G. B. Smith.....	101t	Some Experiments on Internal Oxidation of Nickel Chromium Alloys by H. R. Copson and F. S. Lang.....	194t
Precautionary Procedures in Chemical Cleaning—A Contribution to the Work of NACE Technical Unit Committee T-8A on Chemical Cleaning by Robert A. Stander. Publication 59-1.....	17t	The Corrosion of Zirconium in Hydrochloric Acid at Atmospheric Pressure by W. E. Kuhn.....	103t	Identification of Corrosion Products on Copper and Copper Alloys—A Report of NACE Technical Unit Committee T-3B on Corrosion Products. Publication 59-13.....	199t
Aluminum Cooling Towers and Their Treatment by A. J. Haygood and J. Dean Minford.....	20t	Corrosion in the Corn Wet Milling Industry by Richard Benes, Fred J. Holsinger and Russell E. Pierson.....	113t	Evaluation of Steam Resistant Coatings for Carbon Steel Hospital Ware by E. G. Bobalek, W. R. R. Park, E. G. Bell and W. R. Dawson.....	202t
A Critical Analysis of Pitting Corrosion by N. D. Greene and M. G. Fontana.....	25t	Application Techniques, Properties and Chemical Resistance of Polyethylene Coatings—A Report of NACE Task Group T-6A-5 on Polyethylene. Publication 59-7.....	117t	Delayed Failure of High Strength Steels by Alexander R. Troiano.....	207t
An Electrochemical Study of Pitting Corrosion in Stainless Steels (Part 1—Pit Growth) by N. D. Greene and M. G. Fontana.....	32t	Amount of Annual Purchases of Corrosion Resistant Materials by Various Industries—A Report of NACE Technical Unit Committee T-3C on Annual Losses Due to Corrosion. Publication 59-8.....	121t	The Effect of Sigma Phase vs Chromium Carbides on Intergranular Corrosion of Type 316 and 316L Stainless Steel (Part 1—A Survey of the Literature) by Donald Warren.....	213t
An Electrochemical Study of Pitting Corrosion in Stainless Steels (Part 2—Polarization Measurements) by N. D. Greene and M. G. Fontana.....	39t	Cathodic Protection of Process Equipment—A Report Prepared by NACE Task Group T-3G-3 on Cathodic Protection of Process Equipment. Publication 59-9.....	123t	<b>Technical Topics</b>	
Deterioration of Wood by Marine Boring Organisms by H. Hochman.....	45t	Iso-Corrosion Rate Curves for High Temperature Hydrogen-Hydrogen Sulfide—A Contribution to the Work of NACE Technical Unit Committee T-5 by E. B. Backensto and J. W. Sjöberg. Publication 59-10.....	125t	Materials Selection and Design Problems in a Nickel-Cobalt Extraction Plant by C. S. Simons.....	95
<b>Technical Topics</b>		The Evaluation of Certain Organic Nitrogen Compounds as Corrosion Inhibitors by E. J. Schwoegler and L. U. Berman.....	128t	New Formulations Give Versatility to Urethane Coatings by Bernard Goodman.....	100
Underground Corrosion—A Summary of 45 Years of NBS Research.....	107	Corrosion Inhibitor Testing Inside a Products Pipe Line by Robert H. Meyer.....	131t	Glass Fiber Reinforcement for Coatings—Characteristics and Cost Factors by B. A. Graham.....	102
Rubber-Base Transformer Finish for Severe Environments by Ralph Hockridge.....	111	Factors Influencing the Rate-of-Pickling Test on Tin-Plate Steel by R. M. Hudson and G. L. Stragand.....	135t	Discussion: Page 106 of December 1959 issue.	
Recovery of Graphitically Embrittled Nickel by Walter A. Szymanski.....	112	High Temperature Oxidation of Chromium-Nickel Steels by D. Caplan and M. Cohen.....	141t	<b>May</b>	<b>Page</b>
<b>February</b>	<b>Page</b>	Comparative Corrosion Resistance of 200 and 300 Series Stainless Steels in Chemical Manufacturing Processes by A. C. Hamstead and L. S. Van Delder.....	147t	The Effect of Sigma Phase vs Chromium Carbides on the Intergranular Corrosion of Type 316 and 316L Stainless Steel (Part 2—Laboratory Investigation) by Donald Warren.....	221t
Mechanical Properties and Corrosion Resistance of Oil Well Tubing by F. A. Prange.....	49t	Control of Internal Corrosion of Petroleum Products Pipelines With Oil Soluble Inhibitors by M. R. Barusch, L. G. Haskell and R. L. Plehl.....	158t	Selecting Corrosion and Scale Inhibitors for Cooling Water by Hobart Shields, L. V. Sorg and R. L. Stutz.....	233t
Influence of Service Temperature on the Resistance of Wrought Aluminum-Magnesium Alloys to Corrosion by E. H. Dix, Jr., W. A. Anderson and M. Byron Shumaker.....	55t	<b>Technical Topics</b>		Summary of Questionnaire Replies on Corrosion in HF Alkylation Units—A Report of NACE Task Group T-5A-6 on HF Corrosion. Publication 59-14.....	237t
An Electrochemical Study of Aluminum and Aluminum Alloys by E. M. Khairy and M. Kamal Hussein.....	63t	Behavior of Tin Alloys in Atmospheric Exposures by Robert T. Gore.....	113	Corrosion Prevention in Tankers and Storage Tanks by Fogging or Flotation With an Inhibitor Solution by J. C. D. Oosterhout, M. E. Stanley and W. S. Quimby.....	241t
Topic of the Month—Uses for Varistors with Direct Current Corrosion Meters by W. Searle Woodward.....	68t	Improved Methods Plus Hot Spray Speed Application of Saran Coatings by Harland A. Morley.....	116	Study of Chemical Factors Affecting Corrosion of Carbon Steel AISI 1020 by Liquid-Phase Fuming Nitric Acid by John B. Rittenhouse and David M. Mason.....	245t
Chloride Stress Corrosion Cracking of the Austenitic Stainless Steels—A Contribution to the work of NACE Task Group T-8A on Chemical Cleaning by J. P. Engle, G. L. Floyd and R. B. Rosene. Publication 59-5.....	69t	Bridge Caulking Technique Helps Solve Aerial Pipeline Crossing Problem by Gordon Davis.....	118	Photoelectric Information Selector by R. N. Ride and P. J. Knuckey.....	251t
Well Completion and Corrosion Control of High Pressure Gas Wells—A Status Report of NACE Task Group T-1B-1 on High Pressure Well Completion and Corrosion Mitigation Procedure. Publication 59-6.....	73t	<b>April</b>	<b>Page</b>	Classification of Topics Relating to Corrosion by Miss D. M. Brasher.....	254t
Behavior of AZ 63 Alloy and Magnesium—1 Percent Manganese Alloy Anodes in Sodium Chloride Electrolyte by J. H. Greenblatt and E. Zinck.....	76t	Topic of the Month—Automotive Corrosion Resistance—Past and Present by Leonard C. Rowe.....	167t	Laboratory Methods for Determining Corrosion Rates Under Heat Flux Conditions by A. O. Fisher and F. L. Whitney, Jr.....	257t
Discussion: Page 643t		Corrosion Problems Associated With Uranium Refining by F. H. Meyer, Jr., F. J. Podlipiec and T. R. Kato.....	168t	Influence of Temperature on Corrosion Fatigue by I. Cornet and Simcha Golan.....	262t
Corrosivity of Soil by N. D. Tomashov and Y. N. Mikhailovsky.....	77t				
Variable Interaction: A Statistical Solution by E. C. Bowen, C. Groot and J. L. Jaech.....	83t				
Effect of Molten Boron Oxide on Selected High Temperature Alloys by David Roller and C. R. Andrews.....	85t				

## May—Continued

Erosion of Materials by Cavitation Attack by D. Peckner.....	269t
Acetylenic Alcohol-Inhibited Pickling Bath as a Pretreatment Prior to Lining Steel Pipe by K. N. Edwards, L. J. Nowacki and E. R. Mueller.....	275t
Evaluating the Economy of Reconditioning and Coating Underground Steel Pipe by George M. Pemberton.....	279t

## Technical Topics

High Temperature, High Pressure Testing of Organic Coatings for Oil and Gas Well Tubing by Cordell Garner.....	121
Solving Some Oil Ash Corrosion Problems by R. S. Norris.....	126
Comparative Effectiveness of Coatings for Offshore Drilling Structures by C. G. Munger.....	131

## June

Impedance Characteristics of Isolated Aluminum Oxide Films by D. F. MacLennan.....	283t
Discussion: Page 643t.	
Rates of Dissolution and Passivation of Hafnium-Free Zirconium in Hydrofluoric Acid by M. E. Straumanis, W. J. James and A. S. Neiman.....	286t
Performance of Organic Coatings in Tropical Environments by A. L. Alexander, B. W. Forgeson and C. R. Southwell.....	291t
Discussion: Page 643t.	
Stress Corrosion Crack Paths in Alpha Aluminum Bronze in Ammonia and Steam Atmospheres by J. F. Klement, R. E. Maersch and P. A. Tully.....	295t
Factors Affecting the Corrosion of Steel by Oil-Brine-Hydrogen Sulfide Mixtures by Donald W. Shannon and James E. Boggs.....	299t
An Analytical Procedure for Testing the Effectiveness of Hydrogen Sulfide Corrosion Inhibitors by Donald W. Shannon and James E. Boggs.....	303t
A Laboratory Method for Evaluating Corrosion Inhibitors for Secondary Recovery by T. R. Newman.....	307t
Wash Primer Development and Characteristics by L. R. Whiting.....	311t
Evaluation of Protective Coatings for Ship Bottoms by J. R. Brown.....	315t
Evaluation of Organic Corrosion Inhibitors for Special Applications in Petroleum Refining by R. B. Thompson, R. F. Stedman, Charles Wankat and R. C. Henry.....	321t
Topic of the Month—Effect of Velocity on Life Expectancy of Steel Pipelines in Commercial Strengths of Sulfuric Acid by T. F. Degnan.....	326t
Corrosion of Die Casting Alloys in Detergent Solutions Measured by Electrical Resistance Method by H. J. Smith and R. L. Hadley.....	327t
Progress Report on Inhibiting the Corrosion of Steel in a Reinforced Concrete Bridge by R. F. Stratfull.....	331t

## DISCUSSIONS

Development of the Redox Probe Field Technique: L. P. Sudrabn, Page 335t; Reply by F. E. Costanzo.....	335t
Coatings for Underwater Metal Surfaces in Fresh Water Exposures: Warren D. Palmer, Page 335t; Reply by S. M. Gleser.....	335t
Failure of Type 316 Stainless Steel Autoclave Components: C. P. Dillon, Page 336t; Reply by J. P. Hugo and L. G. Nel.....	336t
Observations on the Mechanisms and Kinetics of Aqueous Aluminum Corrosion: George Panter, Page 336t; Reply by R. L. Dillon.....	336t
Influence of Service Temperature on the Resistance of Wrought Aluminum-Magnesium Alloys to Corrosion: S. K. Nowak, Page 337t; Reply by E. H. Dix, Jr., W. A. Anderson and M. Byron Shumaker.....	338t

## June—Continued

<b>Technical Topics</b>	
Solving Corrosion Problems at Electrical Generating Plants by L. Baskette.....	95
Five Case Histories on Corrosion Problems in Nitric Acid and Ammonium Nitrate Production and Storage by D. M. Carr.....	99
Methods of Testing Characteristics of Polyethylene Jackets for Steel Pipe by H. M. McDaniel.....	100
Corrosion Keeps Knife Sharp on Fruit Canning Machine by S. H. Creed.....	100
Industrial Coating Performance Improved by Good Design by C. G. Munger.....	102

## July

Comparisons of Wagner's Analysis of Cathodic Protection With Operating Data for Ships by J. H. Greenblatt.....	339t
Corrosion Resistance of Titanium and Zirconium in Chemical Plant Exposures by P. J. Gegner and W. L. Wilson.....	341t
Discussion: Page 643t.	
Corrosion of Types 316 and 317 Stainless Steel by 75 Percent and 85 Percent Phosphoric Acid by Albert R. Morgan, Jr.....	351t
Discussion: Page 644t.	
Summary of Replies to Questionnaire on Handling of Chlorine Mixtures—A Report of NACE Task Group T-5A-4 on Chlorine, Publication 59-15.....	355t
Corrosion in Sour Water Strippers by J. F. Mason, Jr., and C. M. Schillmoller.....	358t
Corrosion Protection Features of the Hyperion Ocean Outfall by Harry J. Keeling.....	363t
The Classical Potentiostat: Its Application to the Study of Passivity by N. D. Greene.....	369t
Mechanism of Stress Corrosion of Austenitic Stainless Steels in Chloride Waters by R. W. Staehle, F. H. Beck and M. G. Fontana.....	373t
Corrosion of Reinforcing Steel in Concrete in Marine Atmospheres by D. A. Lewis and W. J. Copenhagen.....	382t
Cathodic Protection of Lead Cable Sheath by W. H. Bruckner and Ole G. Jansson.....	389t
Discussion: Page 644t.	

## Technical Topics

A Field Method for Screening Inhibitors for Prevention of Water Flood Corrosion by Charles C. Wright.....	97
Use of Plastics and Synthetic Elastomers for Underground Coatings by E. G. Partridge.....	101
Mechanism of Stress Corrosion Cracking by Hugh L. Logan.....	106
Coatings Engineers Help in Power Plant Planning by W. J. Prather.....	107

## August

Corrosion of Aluminum Alloy in Glycol-Water Cooling Systems by N. S. Dempster.....	395t
Notch Sensitivity Effects in Stress Corrosion and Hydrogen Embrittlement Tests on High Strength Steels by B. F. Brown.....	399t
Uses and Abuses of Aluminum in Wooden-Hulled, Aluminum-Frame Minesweepers by T. H. Rogers and W. K. Chinn.....	403t
Zinc in Marine Environments by E. A. Anderson.....	409t
Corrosion Problems Associated With Sour Gas Condensate Production by D. R. Fincher.....	413t
The Internal Cathodic Protection of Large Steel Pipes Carrying Sea Water by John H. Morgan.....	417t
Duct Anode Development and Experience in Protection of Underground Cables From Corrosion by J. E. Johnson.....	423t
Discussion: Page 646t.	

## August—Continued

Anchor Pattern Profile and Its Effect on Paint Performance by Joseph Bigos.....	428t
Probability as Related to Stress Corrosion Cracking of Copper Alloys by D. H. Thompson.....	433t
Stress Corrosion Cracking of Oil Country Tubular Goods by R. L. McGlasson and W. D. Greathouse.....	437t
Discussion: Page 646t.	
Corrosion of Type 310 Stainless Steel by Synthetic Fuel Oil Ash by Hugh L. Logan.....	443t

## Technical Topics

Filming Amines Control Corrosion in Utility Plant Condensate System by Edward E. Galloway.....	99
Offshore Platform Shows Corrosion Rate of Carbon Steel in Gulf of Mexico Exposure by Dean Patterson.....	103
Material Selection in Chemical Milling Process by W. C. Rockwell.....	105
Recent Developments in Applying Polyvinylchloride Plastisols by J. Watson Pedlow.....	107
Nickel Alloy Lining Cuts Costs in a Refinery Isomerization Unit by John F. De Lorenzo.....	109

## September

Corrosion Inhibitors for Carbon Tetrachloride—Water Vapor Atmospheres by K. W. Calkins and R. W. Hawley.....	447t
Evaluation of Performance of Screening Tests of Inhibitors to Prevent Chloride Stress Corrosion by J. H. Phillips and W. J. Singley.....	450t
Factors Influencing Corrosion by G. V. Akimov.....	455t
Action of the XON-4 Inhibitors by G. H. Cartledge.....	469t
Design and Materials for Reduced Pump Corrosion by Jack E. Piccardo.....	473t
Corrosion Processes in Carbonated Beverage Cans by E. L. Koehler, J. J. Daly, Jr., H. T. Francis and H. T. Johnson.....	477t
Principles and Criteria for Cathodic Protection of Steel in Sea Water—A Review by M. H. Peterson.....	483t
Planning a Maintenance Coating Program for a Pulp and Paper Plant by M. W. Belue, Jr.....	488t
Four-Tower Water Treatment Test Facility by R. G. Murray and M. E. Tester.....	492t
Use of Magnesium for Cathodic Protection of Pipe Lines in High Resistivity Soil by A. W. Peabody.....	497t

## Technical Topics

Mechanisms and Some Theoretical Aspects of Stress Corrosion Cracking of Austenitic Stainless Steels by W. B. Brooks.....	103
Methods of Installing Cathodic Protection Anodes for Offshore Structures by Wayne A. Johnson and James T. Condry.....	112
Discussion: Page 106 of December 1959 issue.	
Rapid Field Measurement of Sub-Surface Corrosion of Aluminum by Hugh P. Godard.....	114
Case Histories of Differential Aeration Corrosion in Underground Telephone Cables by David T. Jones.....	116

## October

Engineering Approach to a Paint Testing Program—Justification and Economics by D. A. Ballard and V. B. Volkening.....	503t
Methods for Investigating the Characteristics of Reactive Coatings by Max Kronstein.....	508t
Analysis of Industrial Roof Construction and Maintenance by J. C. Lemmon and W. G. Craig.....	513t
Corrosion Inhibitor Evaluation From Cathodic Polarization Measurements by R. A. Legault and Norman Hackerman.....	517t

October—Continued	Page	November—Continued	Page	December—Continued	Page
<b>Some Fundamental Aspects of Materials Deterioration IN THE ATMOSPHERE</b>					
Mechanisms by Which Ferrous Metals Corrode in the Atmosphere by C. P. Larrabee .....	526t	Electrical Bonding of Cathodically Protected to Unprotected Ships by Cdr. G. A. Bennett, N. S. Dempster and A. J. Wallace .....	587t	Corrosion): P. M. Aziz and Hugh P. Godard; Page 642t; Reply by R. L. Dillon, Page 642t.	
Mechanism by Which Non-Ferrous Metals Corrode in the Atmosphere by P. M. Aziz and H. P. Godard .....	529t	Studies on the Susceptibility of Cathodically Protected Steel to Hydrogen Embrittlement by W. H. Bruckner and K. M. Myles .....	591t	Oil Refinery Applications of Thick-Film Synthetic Coatings: Charles M. Stanbury, Emile E. Habib, Austin K. Long, DuWayne Christofferson, Page 642t; Replies by R. W. Maler, Page 642t.	
Principles and Procedures Employed in the Design and Interpretation of Atmospheric Corrosion Tests by H. R. Copson .....	533t	Some Platinum Anode Designs for Cathodic Protection of Active Ships by H. S. Preiser and B. H. Tytell .....	596t	Impedance Characteristics of Isolated Aluminum Oxide Films: F. E. DeBoer, Page 643t; Reply by D. F. MacLennan, Page 643t.	
Deterioration of Materials in Polluted Atmospheres by John E. Yocom .....	541t	The Residual Oil Ash Corrosion Problem—A Review—by C. J. Slunder .....	601t	Behavior of AZ 63 Alloy and Magnesium—1 Percent Manganese Alloy Anodes in Sodium Chloride Electrolyte: J. L. Robinson, 643t; Reply by J. H. Greenblatt, Page 643t.	
Recent Metals Corrosion Articles Published in CORROSION .....	546t	Electrical Resistance Method for Studying Corrosion Inhibitors in Automotive Anti-Freezes by J. C. Cessna .....	607t	Performance of Organic Coatings in Tropical Environments: Seymour J. Flebach, Page 643t; Reply by A. L. Alexander, Page 643t.	
Corrosion Experience Associated With Hydrometallurgical Refining of Nickel at Shearitt Gordon Mines by R. B. McIntosh .....	547t	Effect of Silicon on High Temperature Oxidation of Stainless Steels by John F. Radavich .....	613t	Corrosion Resistance of Titanium and Zirconium in Chemical Plant Exposures: E. G. Brink, Wayne H. Keller, Page 643t; Milton Stern and Claude R. Bishop, Page 644t; Replies by P. J. Gegner, Pages 643t and 644t.	
Simple Screening Test for Determination of Inhibitor Film Persistence by John A. Knox and Roy Stout .....	554t	<b>Technical Topics</b>		Corrosion of Types 316 and 317 Stainless Steel by 75 Percent and 85 Percent Phosphoric Acid: C. M. Schillmoller, Page 644t; Reply by A. R. Morgan, Page 644t.	
<b>Technical Topics</b>		Accumulated Residues Attack Chemical Distilling Column by H. Gilman .....	11-99	Cathodic Protection of Lead Cable Sheath: R. B. Mears, L. C. Eddy, Page 644t; Vernon H. Pike, Frank E. Kulman, J. J. Pokorny, Page 645t; Replies by W. H. Bruckner, Pages 644t, 645t, 646t.	
A Resume of Procedures for Testing and Evaluating Chemical Resistant Coatings and Linings by R. S. Foster and V. B. Volkening .....	85	Can Corrosion Problems by J. J. Daly, Jr. ....	11-100	Duct Anode Development and Experience in Protection of Underground Cables from Corrosion: David T. Jones, Page 646t.	
New Bonding Process Gives Added Versatility to Cladding by R. A. Davis .....	88	Some Properties and Uses of Chlorinated Polyether by C. S. Miller and J. B. Martin .....	11-108	Stress Corrosion Cracking of Oil Country Tubular Goods: H. Lee Craig, Jr., Joe Chittum, Page 646t; Reply R. L. McGlasson, Page 646t.	
Potentialities and Applications of Special Corrosion Resistant Refractories by Roy W. Brown and H. G. Noble .....	92	<b>December</b>		<b>Page</b>	
<b>November</b>		Corrosion in a Hydrocarbon Conversion System by F. A. Prange .....	619t	<b>Technical Topics</b>	
Controlling Internal Corrosion of Tank Ships by J. Franklin Koehler .....	557t	An Industrial Experience of Attack on Metals by Synthesis Gas From Methane-Oxygen Combustion by F. Eberle and R. D. Wylie .....	622t	Characteristic Properties of Polyurethane Protective Coatings by E. R. Wells .....	93
New Instruments and Techniques for Ultrasonic Measurement of Tank Ship Corrosion Losses by Dwight J. Evans .....	561t	High Temperature Deterioration in Atmospheres Containing Carbon-Monoxide and Hydrogen by W. E. Hoyt and R. H. Caughey .....	627t	Corrosion Control Practices in the Wilmington Water Flood Operation by C. H. Jones, Jr. ....	99
Effects of Foreign Metals on Corrosion of Titanium in Boiling 2M Hydrochloric Acid by Roger Buck, III, Billy W. Sloope and Henry Leidheiser, Jr. ....	566t	Corrosion of Metals at Mandapam Camp, India by K. S. Rajagopalan, M. Sundaram and P. L. Annamalai .....	631t	Cathodic Protection of Southern Pacific's High-Pressure Products Pipe Line—Whole System Installed in Nine months by D. N. Miller .....	104
Instruments for Measurements in Underground Corrosion Work by K. G. Compton .....	571t	Case Histories and Ratings vs Corrosives of Polyester Fiber Glass Equipment by Robert E. Barnett and Thomas F. Anderson .....	635t	<b>Technical Topics Discussions</b>	
Equivalent Electrical Circuit Analogy of Structure-to-Soil Potentials by Roy O. Dean .....	576t	<b>DISCUSSIONS</b>		Glass Fiber Reinforcement for Coatings: Austin K. Long, Sol M. Gleser, Page 106; Replies by B. A. Graham, Page 106.	
Service Experience With Lead-Silver Alloy Anodes in Cathodic Protection of Ships by K. N. Barnard, G. L. Christie and D. G. Gage .....	581t	Observations on the Mechanisms and Kinetics of Aqueous Aluminum Corrosion. (Part 1—Role of the Corrosion Product Film in Uniform Aqueous Corrosion of Aluminum; Part 2—Kinetics of Aqueous Aluminum		Methods of Installing Cathodic Protection Anodes for Offshore Structures: Dean C. Glass, Robert L. Davis, Page 106; Replies by Wayne A. Johnson, Page 106.	



# Alphabetical Subject Index

CORROSION Technical and Technical Topics Sections, Volume 15, 1959

**NOTE:** The index is being expanded this year to include Technical Topics as well as Technical Section articles. Designation of Technical Section articles will be made by the appropriate "t" number as has been the custom in the past. For Technical Topics articles both the issue

number of Corrosion and the page number will be given. For example, the notation 9-116 would mean September issue (9th month) of Corrosion, page 116. The notation 10-101 would mean October issue, page 101.

## A

Abrasion, starch granules vs hard rubber and resins, 113t  
Abrasion resistance, plastics, 11-108  
" " " refractories, 10-92  
Abrasives, anchor pattern profile in blast cleaning related to, 428t  
Abstract cards, 254t  
" " " photoelectric information selector used with, 251t  
Abstracts, metals corrosion articles recently published in CORROSION, 546t  
Accelerated testing, steel reinforced by mortar in salt spray, 382t  
" " " atmospheric corrosion of metals, 533t  
Acetals, production of, 311t  
Acetylenic alcohol-inhibited pickling bath for steel pipe, 275t  
ACID  
Acetic, stainless steel (200 and 300 series) vs, 147t  
" " " (Types 316 and 316L) vs, 221t  
Benzoic, inhibition of hydrogen sulfide with, 303t  
Carbonic, iron vs, 526t  
Chromic, inhibiting effect of on aluminum, 7t  
" " " wash primers formed from, 311t  
Citric, stainless steel (Types 316 and 316L) vs, 221t  
Formic, stainless steel (Types 316 and 316L) vs, 221t  
Hydrochloric, austenitic stainless steel equipment chemically cleaned with, 69t  
" " " butane isomerization units vs, 185t  
" " " high nickel-molybdenum alloys in starch production vs, 113t  
" " " mild steel vs, 517t  
" " " mill scale removed with, 17t  
" " " nickel tubing vs, 1-112  
" " " organic coatings for oil well tubing tested in, 5-121  
" " " pumping of into sour gas wells, 413t  
" " " titanium and zirconium resistance to, 341t  
" " " titanium coupled to foreign metals in, 566t  
" " " zirconium at atmospheric pressure vs, 103t  
Hydrofluoric, fuming nitric acid corrosion of AISI 1020 affected by, 245t  
" " " in HF alkylation units, 237t  
" " " rates of dissolution and passivation of hafnium-free zirconium in, 286t

## A—Continued

Nitric, passivation of hafnium-free zirconium in HF after addition of, 286t  
" " " production and storage of, 6-99  
" " " stainless steel (200 and 300 series) vs, 147t  
" " " (Type 304) vs, 257t  
" " " (Types 316 and 316L) vs, 221t  
" " " titanium and zirconium resistance to, 341t  
Nitric (fuming), carbon steel AISI 1020 vs, 245t  
Oxalic, stainless steel (Type 316 and 316L) vs, 221t  
Perchloric, effect of in corrosion of AISI 1020 by fuming nitric acid, 245t  
Phosphoric, aluminum alloys tested in, 63t  
" " " inhibiting effect of on aluminum, 7t  
" " " ship bottom coatings exposed to, 315t  
" " " stainless steel (Type 316) vs, 257t  
" " " (Types 316 and 316L) vs, 221t  
" " " (Types 316 and 317) vs, 351t  
" " " wash primers formed from, 311t  
Sulfuric, aluminum oxide films formed in presence of, 283t  
" " " effect of in corrosion of AISI 1020 by fuming nitric acid, 245t  
" " " lead-acid brick vs, 2-98  
" " " material in nickel extraction plant vs, 4-95  
" " " starch production equipment vs, 113t  
" " " stainless steel (Types 316 and 316L) vs, 221t  
" " " titanium and zirconium resistance to, 341t  
" " " titanium coupled to foreign metals in, 566t  
" " " valve seat ring (Type 316 SS) vs in water treating system, 1t  
" " " velocity of in steel pipe lines, 326t  
Sulfurous, stainless steel (Type 304) vs, 113t  
Acid cleaning of scale and corrosion products, 17t  
Acid stripper tower, HF vs, 237t  
Acid theory of pitting corrosion, 25t  
Acidic environments, inhibitors for steel in, 321t  
Acidization of sour gas wells, 413t  
ACIDS  
Intergranular attack of stainless steels in, 213t  
Mineral, polyurethane coatings vs, 12-93

## A—Continued

ACIDS (Continued)  
Organic, stainless steels vs, 147t  
Polyesters vs, 635t  
Polyethylene coatings vs, 117t  
Refractories used in, 10-92  
Additives, oil ash corrosion from fuel reduced by use of, 5-126  
" " " oil ash corrosion reduced with, 601t  
Adhesive pipe-plastic coating, 6-100  
Admiralty metal, ammonia and hydrogen sulfide vs, 321t  
" " " cooling waters vs, 233t  
" " " inhibited cooling tower water vs, 97t  
" " " inhibitors to protect, 321t  
Admiralty tubes, HF vs, 237t  
Admiralty tubing, stress corrosion cracking of, 433t  
Adsorbed films in pipe lines, behavior of, 158t  
Adsorbed particles in inhibitors, 469t  
Adsorption, inhibitor film persistence related to, 554t  
Adsorption theory of pitting corrosion, 25t  
Adsorptive power of nitrogen compound inhibitors, 128t  
Aeration, phosphoric acid attack of stainless steel measured under conditions of, 351t  
" " " soil corrosivity to buried metals affected by, 1-107  
" " " stress corrosion cracking of copper alloys related to, 433t  
Aerial pipe line crossing, corrosion problems of, 3-118  
Aging of wash primers, 311t  
Air, nickel-chromium alloys oxidized in, 194t  
Air observation of products pipe line, 12-104  
Air oxidation, aqueous corrosion of aluminum related to, 9t  
Air pollution, 541t  
Air preheater tubes, deposits on, 5-126  
Aircraft, high strength steels for, 207t  
Aircraft fuels, inhibitors for in pipe lines, 158t  
Aircraft industry, materials selection in chemical milling process, 8-105  
Aircraft oil cooler, aluminum tubing corrosion of, 395t  
Alclad, good resistance of to perforation in cooling towers, 20t  
Alcohols, acetylenic, inhibiting of pickling bath with, 275t  
Aldehydes, stainless steels vs, 147t  
Alkalies, polyesters vs, 635t  
" " " polyethylene coatings vs, 117t  
" " " refractories used in, 10-92  
Alkaline solution vs lead, 389t  
Alkyd-melamine coating, chemical resistance of at ambient temperatures, 1-111

## A—Continued

Alkyd-phenolic resins, tropical environments vs, 291t  
Alkyds, high-film-build, application of, 171t  
Alkyds, steam resistance of, 202t  
Alkylation units, HF, corrosion in, 237t  
Alloying, steel for industrial and marine atmospheres, 526t  
" " " stainless steel, resistance to pitting affected by, 25t  
ALLOYS  
Aluminum, aqueous corrosion of, 9t, 13t  
" " " electrochemical study of, 63t  
" " " high purity water in at temperatures above 150 C, 7t  
" " " milling process use of, 113t  
" " " nuclear reactors of in low purity water, 83t  
" " " selection of for cooling towers, 20t  
Aluminum-magnesium (wrought), temperature vs, 337t  
Aluminum bronze, stress corrosion crack paths in, 295t  
" " " wrought, testing of for stress corrosion cracking susceptibility, 101t  
AZ 63 and Mg—1 percent Mn anodes in NaCl electrolyte, 76t  
Chrome-nickel, tubes of for dehydrogenation, 619t  
Copper, identification of corrosion products on, 199t  
" " " stress corrosion cracking resistance of, 433t  
Die casting, detergent solutions vs, 327t  
Heterophase and monophase, 455t  
High nickel-molybdenum vs HCl, 113t  
Lead-silver, ship anodes of, 581t  
Molten boron oxide vs at high temperatures, 85t  
Nickel-chromium, internal oxidation of, 194t  
Nickel-chromium - iron - molybdenum, for heat exchangers, 9-103  
Nickel-copper, atmospheric corrosion of, 533t  
" " " titanium coupled with in HCl, 566t  
Oil ash corrosion resistant, 601t  
Sour water stripper components, selection of materials for, 358t  
Tin, atmospheric exposure of, 3-113  
Wrought aluminum - magnesium, influence of service temperature on, 56t  
Alpha aluminum bronze, stress corrosion crack paths in, 295t  
Alumina, bonded fused and fused-cast beta, high temperatures vs, 10-92  
" " " insulating brick of, 10-92

**A—Continued**

Aluminizing for high temperature exposure, 10-92

Aluminizing vs oil ash corrosion, 601t

**ALUMINUM**

Alloy of in glycol-water cooling systems, 395t

Alloys containing vs molten boron oxide, 85t

Anti-freezes vs, 607t

Appearance of in corrosion product formed when AZ 63 exposed to NaCl, 76t

Aqueous corrosion of, 336t, 642t

Atmospheric corrosion of, 529t

Compounds of added to residual fuel oil, 601t

Corrosion of in India, 631t

Electrochemical study of, 63t

Fencing material of for marine atmospheres, 6-95

High temperature corrosion product films on, 7t

Magnesium alloying of vs temperature, 55t

Mechanisms and kinetics of aqueous corrosion of, 9t, 13t

Milling system for, 8-105

Minesweeper with frames of, 403t

Pitting corrosion of, 25t

Sour water stripper components made of vs hydrogen sulfide, 358t

Sub-surface corrosion measurements on, 9-114

Sulfur dioxide vs, 541t

Stress corrosion of, 455t

Titanium coupled with in HCl, 560t

2S, in oxygen-saturated water at 50C, 13t

Aluminum-magnesium alloys (wrought), service temperatures affect, 337t

Aluminum alloy, M-388, deionized water vs, 13t

Aluminum alloys, detergent solutions and tap water vs, 327t

" " M-388 for nuclear reactors, 83t

" " X2219 for nuclear reactors, 83t

" " 1245 for nuclear reactors, 83t

Aluminum brass tubing, stress corrosion cracking of, 433t

Aluminum bronze, alpha, stress corrosion crack paths in, 295t

" " sulfurous acid vs, 113t

" " wrought alloys of vs stress corrosion cracking, 101t

Aluminum cooling towers and their treatment, 20t

Aluminum oxide films, impedance characteristics of, 283t

Aluminum oxide films, isolated, 643t

Aluminum tanks, ammonium nitrate stored in, 6-99

Amino inhibitors in water flood operation, 12-99

Amino scrubber unit, inhibitors in, 189t

Amines, filming, in utility plant condensate system, 8-99

" " sour water strippers protected with, 358t

Amines, glycol-water solution inhibited with, 607t

Amines as inhibitors, 517t

Ammonia, leach solutions of, 547t

" " stress corrosion crack paths of alpha aluminum bronze in atmosphere of, 295t

" " stress corrosion cracking of copper alloys in, 433t

**A—Continued**

Ammonia leach process in nickel refining, 547t

Ammonium fluoride, addition of affects dissolution rate of Zr in HF, 286t

Ammonium nitrate, production and storage of, 6-99

Analysis of variance in determining effects of low purity water in nuclear reactors, 83t

Anchor pattern profile, effect of on paint performance, 428t

Annealing, lag time of tin-plate steel influenced by, 135t

Annealing, stress corrosion cracking of copper alloys affected by, 433t

" " weldments, steel, affected by, 2t

Annealing temperature of zirconium influences corrosion rate in HCl, 103t

Anode assemblies, reinforced concrete bridges having, 331t

Anode beds, magnesium, 497t

Anode cathode relationship between welds and their parent metals, 2t

**ANODES**

AZ 63 alloy and Mg—1 percent Mn alloy in NaCl electrolyte, 76t

Duct, underground, 423t

Graphite, duct, 646t

" " failure of at lead wire connection, 12-106

" " for ships, 581t

" " products pipe line protected with, 12-104

" " underground cable protected with, 423t

Lead-silver alloy for ships, 581t

Magnesium for ships, 581t

" " in high resistivity soil, 497t

" " naval vessels protected with, 2-87

" " steel process equipment protected with, 123t

" " tank ship, 557t

Magnesium-manganese, 643t

Offshore structure installation of, 9-112

Platinum, for ships, 581t, 596t

" " submarine protected with, 2-87

Sacrificial, steel pipe sewer outfall in ocean unsuitable for, 363t

Ship, 339t, 581t, 587t

Silicon iron, underground cable protected with, 423t

Steel, for ships, 581t

Steel pipe protected with inside mounting of, 417t

Zinc, chemical process equipment protected with, 123t

" (sacrificial), aluminum frame minesweeper use of, 403t

" " pipe line in ocean protected with during installation, 363t

Anodic behavior, aluminum alloys tested by repetitive oscillographic method, 63t

Anodic reactions in pitting of metals, 25t

Anti-freezes, automobile, inhibition of, 607t

Antimony, titanium coupled with in HCl, 566t

**APPLICATION**

Chlorinated polyether, 11-108

Coal tar-epoxy resins for underground pipe, 7-101

Coatings on steel structures, 6-102

Hot spray coating of Saran, 3-116

**A—Continued****APPLICATION (Continued)**

Polyvinylchloride plastisols, 8-107

Pulp plant coatings, 488t

Steam resistant coatings to carbon steel hospital ware, 202t

Thick-film synthetic coatings in oil refineries, 171t

Application techniques, polyethylene coatings, 117t

Applied potential, effect of on corroding aluminum, 9t

Aqueous corrosion, aluminum, 642t

" " aluminum and its alloys, 7t, 9t, 13t

Aqueous hydrogen sulfide vs refinery equipment, 189t

Aqueous uranyl nitrate vs stainless steels, 168t

Aqueous systems, dynamic, hydrogen effusion measurements in, 179t

Aromatics, polyethylene vs, 6-100

Arsenic, flood water inhibited with, 12-99

Artificial pit specimens, use of in pitting studies on stainless steels, 32t

Artificial pits, use of in study of pitting corrosion, 25t

Asphalt coatings, underground pipe, 7-101

Asphalt emulsion, offshore structure use of, 5-131

Asphalt mastic, rubberized, coatings of on offshore drilling structures, 5-131

Asphalt roofing, 513t

Atmosphere, industrial and marine vs ferrous metals, 526t

" " inland, organic coatings vs in tropics, 291t

" " marine, organic coatings vs in tropics, 291t

Atmospheres, carbon monoxide and hydrogen containing, metals vs, 627t

" " polluted, materials deterioration in, 541t

**ATMOSPHERIC CORROSION**

Coatings selection against, 10-85

Ferrous metals vs, 526t

Industrial, reinforced concrete cracks in, 382t

Inhibitors to combat, 447t

Materials deterioration from, 541t

Tests, 533t

Tin alloys, 3-113

Titanium, zirconium and other metals, 341t

Zinc and galvanized steel, 409t

Zinc, copper and mild steel in India, 631t

Atmospheric corrosivity in different countries, 533t

Atmospheric salinity, metals corrosion related to, 631t

Augelite forms as corrosion product on aluminum alloys, 7t

Autocatalytic nature of pitting process in metals, 25t

Autoclave, oxidation, lead-acid brick used to reline, 2-98

Autoclaves, leaching, Type 316 stainless steel, 547t

Automobile anti-freezes, inhibition of, 607t

Automobile paint, air pollution vs, 541t

Automotive corrosion resistance, 167t

AZ 63 alloy and Mg—1% Mn alloy anodes in NaCl electrolyte, 76t

**B**

Backfill, gypsum moulding plaster, 497t

Bacteria, underground corrosion accelerated by, 1-107

Bactericides, aluminum compatible with in cooling towers, 20t

Baffles, reaction gases vs, 622t

Baking, hydrogen eliminated from high strength steels by, 207t

Bentonite clay emulsions for industrial roofing, 513t

Bibliography, abstracts of metals corrosion articles recently published in CORROSION, 546t

Biological corrosion, marine boring organisms vs wood, 45t

Bismuth, titanium coupled with in HCl, 566t

Bitumen, roofing of, 513t

Bitumens, tropical environments vs, 291t

Bituminous coatings, steam resistance of, 202t

Blast cleaning rates on steel, 428t

Bleed steam system, materials selection for, 4-95

Boehmite, formation of in anodized aluminum, 283t

Boehmite forms as corrosion product film on aluminum alloys, 7t

Boiler, waste heat type, 622t

Boiler water, inhibition of, 450t

Boilers, alkalies vs, 455t

" " oil ash corrosion problems in, 601t, 5-126

Bolts, aluminum, sea water exposure of, 403t

Bonding, electrical, of ships, 587t

" " lead to steel, 4-95

Bonding process, cladding versatility increased by, 10-88

Borax, inhibition of anti-freezes with, 607t

Boron oxide, molten, high temperature alloys vs, 85t

Brass, anti-freezes vs, 607t

" " atmospheric corrosion of, 533t

" " cast high tensile, erosion resistance of, 269t

Breakaway corrosion, zirconium in HCl, 103t

Breaks in rate curves related to stainless steel scaling, 141t

Brick, bubble alumina insulating, 10-92

" " lead-acid, in chemical plants, 2-98

" " paving, impingement tests on, 10-92

Bridge caulking technique solves aerial pipe line crossing problem, 3-118

Bridges, reinforcing steel in concrete corrodes in marine atmospheres, 382t

Brine, flood water containing, 307t

Brine-hydrogen sulfide systems, stress corrosion cracking in, 437t

Brine-oil-hydrogen sulfide mixtures vs steel, 299t, 303t

Brine solution, corrosion fatigue of steel in, 262t

Brittle fracture, pipe at low temperature, 591t

Bronze, alpha aluminum, stress corrosion crack paths in, 295t

" " aluminum alloyed, wrought, stress corrosion cracking of, 101t

" " atmospheric corrosion of, 533t

Bronze compared to copper under nickel/chromium, 3-113

Bronze under copper and nickel, resistance of, 3-113

Bubble caps, residues vs, 11-99

**B—Continued**

- Buffering in inhibitor evaluation, 517t
- Building materials vs sulfur dioxide, 541t
- Bulk and barrier films, aluminum in aqueous solutions related to, 9t
- Bunker-C oil, oil ash corrosion problems involving, 601t
- Butane dehydrogenation process, 619t
- Butane isomerization units, minimum corrosion for, 185t
- Butoxy resins, underground pipe protected with, 7-101
- Butyl rubber, underground pipe coated with, 7-101

**C**

- "C" factor in inhibitor evaluation inside pipe lines, 131t
- Cable sheath, lead, cathodic protection of, 389t
- "", measurements on, 571t
- Cables, bare, in sea water, coatings for, 7-101
- "", underground, differential aeration on, 9-116
- "", duct anodes to protect, 423t
- Cadmium, synergized polyphosphate containing, 97t
- "", plating of on aircraft steels, 207t
- "", tin as undercoat on, 3-113
- "", titanium coupled with in HCl, 566t
- Calcium, compounds of added to residual fuel oil, 601t
- Calcium chloride, titanium and zirconium resistance to, 341t
- Calcium phosphate, deposition of in cooling tower water, 97t
- Canned product processing, 11-100
- Canned-motor type centrifugal pump, 473t
- Canning, fruit, cutter blade sharpened by corrosion, 6-100
- Cans, carbonated beverage, 477t
- "", corrosion of, 11-100
- Carbide precipitation, intergranular corrosion of stainless steels related to, 213t
- Carbon dioxide and atmospheric corrosion, 541t
- Carbon dioxide in electric utility plants, 8-99
- Carbon monoxide as a hydrogen sulfide inhibitor, 303t
- Carbon monoxide, atmospheres containing, metals vs, 627t
- "", internal oxidation of nickel-chromium alloys in, 194t
- "", lag time of tin-plate steel influenced by, 135t
- Carbon pick up, avoiding of on clad sheet welding, 10-88
- Carbon tetrachloride-water vapor atmospheres, inhibitors for, 447t
- Carbonated beverage cans, 477t
- Carburization attack, tubing affected by, 627t
- Carburization in methane-oxygen combustion, 622t
- Carburization in 80-20 nickel chromium, 194t
- Cargo tanks, protection of, 557t
- Casing, high pressure gas well, materials for, 73t
- Catalytic reforming process, hydrogen sulfide vs steels in, 125t
- Catalytic reforming units, inhibition of, 189t

**C—Continued**

- Catalyst cured phenolics and epoxies in refinery applications, 171t
- Catalyst cured epoxy-modified phenolics, refinery applications of, 171t
- Catalyst tube, materials selection for, 619t
- Cathode electrode area, polarization characteristics of pit specimens related to, 39t
- Cathode ray tube, ultrasonic resonance device, 561t
- Cathodic inhibitors, cooling tower water treated with, 97t

**CATHODIC PROTECTION**

- AZ 63 alloy and Mg-1% Mn alloy anodes in NaCl electrolyte, 76t
- Duct anode development, 646t
- Duct anodes for underground cable, 423t
- High pressure products pipe line, 12-104
- Inhibitor evaluation from measurements from, 517t
- Lead cable sheath, 389t, 644t
- Minesweepers, aluminum-frame, 403t
- Naval vessels, 403t, 2-87
- Offshore structures, 9-112
- Pipe lines in high resistivity soil, 497t
- Pipe lines in soil, 335t
- Process equipment, 123t
- Reinforcing steel in concrete, 382t
- Ship operating data compared with Wagner's analysis, 339t
- Ships, 339t, 403t, 483t, 557t, 581t, 587t, 596t, 2-87
- Soil corrosivity measurements, methods used in making, 77t
- Steel in reinforced concrete bridge, 331t
- Steel in sea water, 483t
- Steel pipes carrying sea water, 417t
- Steel pipe sewer outfall in ocean, 363t
- Stray current potentials measured, 68t
- Stress corrosion cracking of magnesium alloy stopped by, 7-106
- Structure-to-soil potentials, 576t
- Tank ships, 557t
- Underground corrosion reduced by (NBS summary), 1-107
- Underground telephone cables, 9-116
- Cathodically protected steel, hydrogen embrittlement of, 591t
- Cations, metallic, effect of on potential of titanium in HCl, 566t
- Caulking materials, application of, 3-118
- Causes of underground corrosion, NBS investigations of, 1-107
- Caustic embrittlement, iron and steel, 455t
- Cavitation attack, erosion of materials by, 269t
- Cells, corrosion, peculiarities of, 76t
- Cement mortar, steel pipe sewer outfall in ocean coated with, 363t
- Cement ratio to water, variation of for reinforced steel, 382t
- Central point anode system in coated pipe, 417t
- Centrifuging of fuel reduces oil ash corrosion, 5-126
- Ceramic coatings vs fuel oil ash corrosion, 601t

**C—Continued**

- Ceramic materials, wood and glass, annual purchases of by industries, 121t
- Ceramic-ware vs chlorine mixtures, 355t
- Ceramics, special corrosion resistant refractories, 10-92
- "", valve trim, 4-95
- Characteristics of reactive coatings, 508t
- Chemical and process industry, pumps for, 473t
- Chemical cleaning, safety in, 17t
- Chemical distilling column, accumulated residues attack, 11-99
- Chemical industry, annual purchase of corrosion resistant materials by, 121t
- "", cathodic protection of process equipment in, 123t
- Chemical injection, in flood water, 7-97
- "", in sour gas wells, 413t
- Chemical manufacturing processes, 200 and 300 series stainless steels in, 147t
- Chemical milling, materials selection in, 8-105
- Chemical plants, lead-acid brick systems in, 2-98
- "", paint testing program in, 503t
- "", titanium and zirconium resistance in, 341t
- Chemical stability of metals, 455t
- Chemical treatment, water flooding, 12-99
- Chemical treatment of filled cans, 11-100
- Chloride ions in pitting of metals, 25t
- Chloride ions, aluminum alloy behavior in presence of, 63t
- Chloride stress corrosion cracking, stainless steel, 69t, 450t
- CHLORIDES**
- Aluminum aircraft cooler vs, 395t
- Austenitic stainless steel, stress cracking in, 373t
- Heat exchanger tubing exposed to, 6-99
- Heat exchangers vs, 9-103
- Sour water strippers vs, 358t
- Stainless steel tank vs, 547t
- Stainless steels (200 and 300 series) vs, 147t
- Steel-reinforced concrete vs, 382t
- Uranium refining corrosion associated with, 168t
- Chlorimet 3, chemical plant exposures vs, 341t
- Chlorinated polyether, properties of, 11-108
- Chlorinated rubber mastic for offshore structures, 5-131
- Chlorinated rubber over wash primers, 311t
- Chlorinated rubber, properties of, 12-93
- Chlorine, hot, silicon carbide vs, 10-92
- "", titanium and zirconium vs, 341t
- Chlorine mixtures, materials used to handle, 355t
- Chloroprene rubber paint, resin-modified, on transformers, 1-111
- Chlorosulphonated polyethylene, underground pipe coatings of, 7-101
- "", pump linings of, 473t
- Chromate type inhibitors, 469t

**C—Continued****CHROMATES**

- Aluminum cooling towers inhibited with, 20t
- Cooling waters inhibited with, 233t
- Inhibiting effect of on aluminum, 7t
- Inhibition with, 455t
- Pitting attack inhibited with, 269t
- Reactive coatings based on, 508t
- Chrome magnesite, high temperatures vs, 10-92
- Chromic phosphate in PVB forms wash primers, 311t
- Chromizing alloys vs oil ash corrosion, 601t
- Chromium, oxidation of in nickel alloys, 194t
- Chromium alloying of steel, 526t
- Chromium carbides, stainless steel (Types 316 and 316L) affected by, 213t, 221t
- Chromium enrichment in metal-oil interface on stainless steel, 613t
- Chromium-nickel alloys, high temperature vs, 619t
- Chromium-nickel steels, high temperature oxidation of, 141t
- Citrates enhance corrosion of aluminum in water, 9t
- Clad material, Type 316 ELC, 547t
- Clad plate, size and thickness of, 10-88
- Clad platinum anodes for ships, 596t
- Cladding, new bonding process in, 10-88
- Cladding materials, new types of available, 10-88
- Classification of topics relating to corrosion, 254t
- Clay-bonded silicon carbide liners, 10-92
- Cleaning, chemical, HCl vs stainless steel, 69t
- Cleaning, lag time of tin-plate steel influenced by, 135t
- Climatic conditions, metals testing related to, 631t
- Cleaning techniques for steel to be painted, 428t
- Coal tar and asphalt coatings, glass fiber reinforcement of, 4-102
- COAL TAR**
- Enamel for steel pipe in ocean, 363t
- Epoxies, underground corrosion of pipe reduced with, 7-101
- Linings for water tanks, 12-99
- Systems in tropical sea water, 291t
- Underground corrosion reduced with, 7-101
- Wrap, offshore drilling structures coated with, 5-131
- Coal-to-oil synthesis plant, corrosion in, 627t
- COATINGS**
- Aerial pipe line crossing, problems in, 3-118
- Aluminum box for sea water exposure, 403t
- Annual purchases of by industries, 121t
- Baked phenolic, 1-107
- Baked phenolic-epoxy, on oil wells, 49t
- Bituminous, underground tests on, 1-107
- Carbonated beverage can interior, 477t



**C—Continued****COATINGS (Continued)**

Cement-mortar on steel pipe in ocean, 363t  
 Chemical resistant, testing of, 10-85  
 Chlorinated polyether, properties of, 11-108  
 Coal tar enamel with fiber glass reinforcing, 368t  
 Concrete reinforced with steel, 382t  
 Design factors on structures improve efficiency of, 6-102  
 Economics of paint test program, 503t  
 Enamel, underground corrosion tests on, 1-107  
 Epoxy-phenolic for steel pipe, 275t  
 Fuel oil ash corrosion attack reduced by, 601t  
 Galvanized on buried iron and steel, 1-107  
 Glass fiber reinforcement of, 4-102  
 Gunite on sour water strippers, 358t  
 High pressure products pipe line, 12-104  
 Hot spray, Saran, shipyard application of, 3-116  
 Maintenance of in chemical milling process, 8-105  
 Metallic, mild steel sterilizers tested having, 202t  
 ", steel in industrial and marine atmospheres, 3-113  
 ", zinc and aluminum, aqueous hydrogen sulfide vs, 189t  
 Offshore drilling structure, 5-131  
 Oil-modified phenolic, transformers using, 1-111  
 Organic, for oil and gas well tubing, 5-121  
 ", in tropical environments, 291t  
 ", polyethylene vs acids, alkalies and salts, 117t  
 Plastics and synthetic elastomers for underground coatings, 7-101  
 Plastics for high pressure gas well tubing, 73t  
 Polyethylene jackets for steel pipe, 6-100  
 Polyurethane, properties of, 12-93  
 Polyvinylchloride plastisols, 8-107  
 Power generating plant equipment, 6-95  
 Power plant, 7-107  
 Pulp and paper plant, 488t  
 Pump, 473t  
 Reactive, characteristics of, 508t  
 Resistances of on pipe lines in high resistivity soils, 497t  
 Rubber, underground corrosion tests on, 1-107  
 Ship bottom, 315t  
 Ship hull, 483t, 587t  
 Sprayed, 12-106  
 Sprayed zinc in marine environments, 409t  
 Steam-resistant for carbon steel hospital ware, 202t  
 Steel pipe interior for carrying sea water, 417t  
 Synthetic rubber and vinyl, 643t  
 Tank ship internal structure, 557t  
 Thick-film, 642t  
 ", synthetic, oil refinery, 171t  
 Tin coated plate, 11-100  
 Underground steel pipe, cost of, 279t

**C—Continued****COATINGS (Continued)**

Underwater metal for fresh water exposure, 335t  
 Urethane, 4-100  
 Water storage tank, 12-99  
 Coatings engineers, role of in power plant designing, 7-107  
 Coatings plus cathodic protection, potential profiles of, 576t  
 Cobalt, titanium coupled with in HCl, 566t  
 Cobalt-base alloys, Stellite 25 vs molten boron oxide at 1957F, 85t  
 Coding of corrosion information, 251t, 254t  
 Coils, carbon steel, in nickel refining, 547t  
 Columbium, nickel chromium alloys containing, 194t  
 Completion methods on sour gas wells, 413t  
 Completion practices in high pressure gas wells, 73t  
 Composite coatings for offshore drilling structures, 5-131  
 Compounding, polyethylene coatings modified by, 117t  
 Compression of sour gases, 413t  
 Concrete, leaching of, 547t  
 Concrete, steel reinforced, 331t  
 ", sulfur dioxide fumes vs, 113t  
 Concrete flooring, epoxies for, 12-106  
 Concrete liners at source wells, 12-99  
 Concrete pipe in power plants, 6-95  
 Concrete reinforced with steel, 382t  
 Condensate, sour gas, 413t  
 Condensate system, utility plant, filming amines used in, 8-99  
 Condenser tube corrosion, 6-95  
 Condenser tubes, steel, water contaminated with hydrogen sulfide vs, 189t  
 ", stress corrosion cracking of, 433t  
 Conductor pipe, steel, offshore platform, 8-103  
 Conduit systems, telephone cable, 9-116  
 Contactor shells, HF vs, 237t  
 Conversion system, hydrocarbon, 619t  
 Cooling system, glycol-water, aluminum alloy in, 395t  
 ", minesweeper, metals selection for, 403t  
 ", nuclear fuel element jacketing of, 83t  
 Cooling towers, aluminum, treatment of, 21t  
 ", polyvalent ion - polyphosphate inhibitors in, 97t  
 ", thick-film synthetic coatings for, 171t  
 Cooling water, 233t, 413t, 417t, 547t, 9-103  
**COPPER**  
 Anti-freezes vs, 607t  
 Atmospheric corrosion of, 529t  
 Canned goods containing, 11-100  
 Corrosion of in India, 631t  
 Corrosion products identified on, 199t  
 Deposits of on aluminum aircraft cooler, 395t  
 Filming amines used to protect in condensate cycle, 8-99  
 High temperature gases vs, 622t  
 Steels containing for atmospheric exposure, 533t  
 Sulfides vs, 529t  
 Sweet corrosion cracking of, 437t  
 Titanium coupled with in HCl, 566t

**C—Continued**

Copper alloying of steel, 526t  
 Copper alloys, soils vs, 1-107  
 ", stress corrosion cracking of, 101t, 433t  
 Copper containing compounds vs marine borers, 45t  
 Copper evaporator tubes, failure of in starch production service, 113t  
 Copper heating coils in zinc chloride concentrating tanks, 123t  
 Copper ion displacement test, inhibitor rating by, 554t  
 Copper removal in nickel refining, 547t  
 Copper tubing, water tower, 492t  
 Corn wet milling industry, corrosion in, 113t  
 Corrosion fatigue, 262t, 455t  
 Corrosion product films on aluminum, 7t, 9t  
 Corrosion products on copper alloys, identification of, 199t  
 Corrosivity of soil, 77t  
 Couples, titanium-foreign metals in HCl, 566t  
 Crack growth behavior of modified Type 422 steel, 399t  
 Crack initiation, mechanism of for austenitic stainless steels in chlorides, 373t  
 ", propagation and fracture in high strength steels, 207t  
 Crack propagation pattern, stressed austenitic stainless steel in chlorides, 373t  
 Cracking, notch specimens of high strength steels, 207t  
 ", reinforced concrete in marine atmospheres, 382t  
 ", transgranular, austenitic stainless steels in chlorides, 69t  
 ", tube sheets, 6-99  
 Creep data for chlorinated polyether, 11-108  
 Creosoting of wood to reduce marine borer attack, 45t  
 Crevice corrosion, Type 316 stainless steel in starch, 113t  
 Crevices, elimination of in design—industrial structures, 6-102  
**CRITERIA**  
 Anode design for ships, 596t  
 Cathodic protection, cement mortar coated steel pipe in ocean, 363t  
 ", pipe lines in high resistivity soils, 497t  
 ", process equipment, 123t  
 ", ships, 581t  
 ", steel pipe carrying sea water, 417t  
 ", steel pipe in sea water, 483t  
 Crude and refined petroleum products industry, annual purchase of corrosion resistant materials by, 121t  
 Crude petroleum and natural gas production industry, annual purchase of corrosion resistant materials by, 121t  
 Crystalline structures of corrosion product films on aluminum, 7t  
 Crystallization of barrier films in air on aluminum, 9t  
 Cupro nickel (70-30), stress corrosion cracking, 433t  
 Curing of cement for reinforcing steel, 382t

**C—Continued**

Current measurement, underground corrosion, 571t  
 Current shields, polychloroprene, on ships, 581t  
 Cyanides in chemical cleaning, dangers from, 17t  
 Cycling oxidation and reduction, 622t  
**D**  
 Data, corrosion, classification of, 254t  
 ", photoelectric selector used for, 251t  
 DC technique, ship bottom coatings evaluated by, 318t  
 Debutanizer systems, HF vs, 237t  
 Dehydration of sour gases in processing plants, 413t  
 Dehydrogenation process, butane, 619t  
 Delayed failure of high strength steels, 207t  
 Denison method, soil corrosivity measured by, 77t  
 Depropanizer system, HF vs, 237t  
**DESIGN**  
 Cathodic protection system for pipe lines, 497t  
 Coating efficiency on structures in connection with, 6-102  
 Heat exchanger tubing, 6-99  
 Heat exchangers, 9-103  
 Offshore drilling platforms, 6-102  
 Platinum anodes for ships, 596t  
 Power plant, role of coatings engineers in, 7-107  
 Pump, 473t  
 Refinery isomerization unit, nickel alloy lining for, 8-109  
 Sour gas plant, 413t  
 Streamlining reduces cavitation attack, 269t  
 Tank truck reinforcement, 2-94  
 Design factors in chloride stress corrosion of austenitic steel, 69t  
 Design problems, in high pressure gas well installation, 73t  
 ", in nickel-cobalt extraction plant, 4-95  
 Detergent solutions, die casting alloys in, 327t  
 Detinning, internal, 11-100  
 Dew point, depressing of in Diesel engine fuel, 5-126  
 Dezincification of brass, 455t  
 Diaphragm type pumps, 473t  
 Diamine, cyclic, preparation of, 147t  
 Dichromate sealer, 508t  
 Diesel engines, oil ash corrosion of, 5-126  
 Diesel fuel, oil ash corrosion problems of, 601t, 6-126  
 Die casting alloys in detergent solutions, 327t  
 Diethanolamine, hydrogen sulfide stripped from solutions of, 358t  
 Diethylenetriamine as a hydrogen sulfide inhibitor, 303t  
 Differential aeration corrosion in underground telephone cables, 9-116  
 Differential aeration, metal surface in soil, 77t  
 Dimensional stability of chlorinated polyether, 11-108  
 Dip coating of polyvinylchloride plastisols, 8-107  
 Dispersants, inhibitor, flue gas used as, 241t  
 Dissolution and passivation of hafnium-free zirconium in HF, 286t

**D—Continued**

- Distilling column, chemical, residues vs, 11-99
- DK alloy (aluminum), electrode potential behavior of in buffer solutions, 63t
- Docks and piers, boring organisms vs, 45t
- Dolomite, oil ash corrosion reduced by addition of, 601t
- Drainage, atmospheric corrosion testing, 533t
- Drilling mud (high pH), organic coating for tubing tested in, 5-121
- Drums, propane, lining of, 171t
- Drydock variables affect ship bottom coatings, 315t
- Duct anodes, graphite, 646t
- Duct anodes, underground cables protected with, 423t
- Ductility, transverse, relationship of to failure of oil well tubing strings, 49t
- Ductwork, polyester fiber glass for, 635t
- Duomeen 12 D as a hydrogen sulfide inhibitor, 303t
- Duplex corrosion films on oxidized aluminum, 9t
- Duralumin, atmospheric corrosion of, 533t
- "", electrode potential behavior of in phosphoric acid and buffer solution, 63t
- Duranickel bolting, HF vs, 237t
- Duriron, high temperature vs, 619t
- Dust, red oxide, in dehydrogenation process, 619t
- Dye, Azo, effect of on corrosiveness of soft drinks, 11-100
- Dyes, ozone vs, 541t
- Dynamic aqueous systems, hydrogen effusion measures corrosion rate in, 179t

**E****ECONOMICS**

- Annual purchases of corrosion resistant materials by industries, 121t
- Anode installations for destroyers, 581t
- Boiler fouling and corrosion, 5-126
- Cathodic protection of process equipment, 123t
- Coatings and linings, 10-85
- Coatings for underground pipes, 7-101
- Engineering approach to a paint testing program, 503t
- Glass fiber reinforcement for coatings, 4-102
- High pressure gas well completion methods, 73t
- Industrial roofing replacement vs maintenance, 513t
- Internal cathodic protection of pipes carrying sea water, 417t
- Membrane linings for brick, 2-98
- Nickel alloy lining in refinery isomerization units, 8-109
- Plastic reinforcement of tank trucks, 2-94
- Pulp plant coating program, 483t
- Reconditioning and coating underground steel pipe, 279t
- Saran coating by hot spray, 3-116
- Tank ship corrosion, 557t
- Titanium and stainless steel pumps, 473t

**E—Continued**

- Elastomers, air pollutants vs, 541t
- "", synthetic, underground coatings of, 7-101
- Electric drain of stray currents, 455t
- Electric furnace Mullite, high temperature vs, 10-92
- Electric light and power industry, annual purchase of corrosion resistant materials by, 121t
- Electric utility plant, filming amines used in condensate system of, 8-99
- Electric-weld tubing, use of in oil wells, 49t
- ELECTRICAL**
- Bonding of cathodically protected to unprotected ships, 587t
- Characteristics of aluminum oxide films, 283t
- Circuit analogy, 576t
- Generating plants, 6-95
- Electrical resistance method, antifreeze inhibitors studied with, 607t
- "", die casting alloy corrosion in detergent solutions measured by, 327t
- "", flood water corrosion inhibitors rated by, 7-97
- "", use of to measure corrosion, 215t

**ELECTROCHEMICAL**

- Aspects of pitting corrosion, 25t
- Behavior of passive metals, 369t
- Control in pitting corrosion of stainless steels, 25t
- Method, soil corrosivity measured by, 77t
- Reactions in aqueous hydrogen sulfide corrosion of steel, 189t
- Study of aluminum and its alloys, 62t
- Study of pitting corrosion in stainless steels, 32t, 39t
- Theory of iron corrosion, 526t

- Electrode kinetics in inhibitor study, 469t
- Electrodes, calomel, offshore structure use of, 12-106
- "", reference, 576t
- "", on ships, 581t
- "", underground corrosion measurements involving, 571t
- Electrolytic method, soil corrosivity measured by, 77t
- Electron microscopy used to study corrosion product films on aluminum, 7t
- Enamel lifting from cans, 11-100
- Enamels, synthetic, tropical marine atmospheres vs, 291t
- Energies and entropies of activation compared in aluminum corrosion, 13t
- Engineering approach to a paint testing program, 503t
- Epoxies, catalyzed, caulking materials of, 3-118
- "", concrete floors protected with, 12-106
- "", modified, steam resistance of, 202t
- "", tropical environments vs, 291t
- Epoxy, amine cured, testing of for oil well tubing coating, 5-121
- "", catalyst cured, refinery application of, 171t
- "", properties of, 12-93
- Epoxy coatings, catalyzed, offshore drilling structure use of, 5-131
- Epoxy liner, field joints of steel pipe in ocean used with, 363t

**E—Continued**

- Epoxy modified phenolics, catalyzed, 642t
- "", refinery applications of, 171t
- "", testing of for oil well tubing coating, 5-121
- Epoxy resins, suitability of for reducing underground corrosion, 7-101
- Epoxy-phenolic coating, starch production equipment protected with, 113t
- "", steel pipe protected with, 275t
- Equivalent electrical circuit analogy of structure-to-soil potentials, 576t
- Erosion of materials by cavitation attack, 269t
- Erosion-corrosion, turbines in electric utility plants vs, 8-99
- Esters, stainless steels with, 147t
- Etchants in chemical milling process, 8-105
- Ethylene diamine, brass in glycol-water solution inhibited with, 607t
- Ethylene glycol vs mild steel, 607t
- Evacuation system, HF vs, 237t
- Evaluating inhibitors from cathodic polarization measurements, 517t
- Evaluating the economy of reconditioning and coating underground steel pipe, 279t
- Evaluation of organic nitrogen compounds as inhibitors, 123t
- Evaluation of inhibitors inside pipe lines, 131t
- Evaluation of steam resistant coatings for carbon steel hospital ware, 202t
- Evaluation program, chemical resistant coatings and linings, 10-85
- Exhaust fumes, lead-acid brick vs, 2-98
- Extraction of nickel by Moa Bay process, 4-95

**F**

- Fabrication, clad plate, 10-88
- Fabrication procedure, nickel alloy lining for refinery isomerization unit, 8-109
- Factors influencing corrosion, 455t
- Factors influencing rate-of-pickling test on tin-plate steel, 135t
- Fatigue, corrosion, influence of temperature on, 262t
- Fatigue curves, static, high strength steel, 207t
- Fence, galvanized, marine atmosphere vs, 6-95
- Ferric ion concentration, pitting tendencies of with stainless steels, 32t
- Ferric oxide rust on cans, 11-100
- Ferrocyanide ion addition to polyphosphate for cooling tower water inhibition, 97t
- Ferrous metals, atmosphere vs, 526t
- "", soils vs, 1-107
- Ferrous oxide, hydrogen embrittlement in presence of, 591t
- Fiber glass, polyester, 635t
- Fiber types, glass, comparison of, 4-102
- Field measurements of sub-surface aluminum corrosion, 9-114
- Field method to screen inhibitors for water flood corrosion prevention, 7-97
- Film, corrosion information recorded on for quick sorting, 251t

**F—Continued**

- Film persistence, inhibitor, 654t
- Filming amines control corrosion in utility plant condensate system, 8-99
- FILMS**
- Aluminum oxide, 283t, 643t
- Corrosion product, role of in uniform aqueous corrosion of aluminum, 9t
- "", on aluminum in high purity water, 7t
- Oxide, on iron, 526t
- "", on stainless steels at high temperatures, 613t
- Protective, phenomena on steels, 526t
- Thin, on stainless steel, 613t
- Zirconium in HCl forms various types of, 103t
- Zirconium oxide, protective properties of in HCl, 103t
- Filters, carbon steel, for nickel refining, 547t
- "", pipe line, 131t
- Finish, rubber base, for protecting transformers, 1-111
- Fireclay, high temperatures vs, 10-92
- Fish oil, coatings of on offshore drilling structures, 5-131
- Fitting anodes on ships, 581t
- Flame cleaning of bubble caps, 11-99
- Flexible metal results from corrosion of Type 316 valve seat rings, 1t
- Flood waters, 12-99
- Flotation, inhibition in tankers and storage tanks, 241t
- Flue gas, effect of additives on in boilers, 5-126
- Fluorides, uranium refining equipment vs, 168t
- " (alkali), passivation of hafnium-free zirconium in HF after addition of, 286t
- Fluorine, polymers containing, pipe protected with, 7-101
- Fluoro chloro hydrocarbon, properties of, 11-108
- Fluozirconates, solubilities of, 286t
- Fogging, inhibitors in tankers and storage tanks, 241t
- Food packing, can corrosion problems in, 11-100
- Food processing, corn wet milling industry vs corrosion, 112t
- "", tin plate as containers in, 135t
- Food product corrosivity to cans, testing of, 11-100
- Foreign metal ions, titanium in boiling HCl affected by presence of, 566t
- Formulations of urethane coatings, 4-100
- Formvar, steam resistance of, 202t
- Fouling, boiler, 5-126
- "", reduction of on aluminum with copper-base paints, 403t
- Fracture, mechanical and stress corrosion on high strength steels, 399t
- Fruit canning, cutter blade sharpened by corrosion in, 6-100
- Fuel oil ash, synthetic, Type 310 stainless steel vs, 443t
- Fuel oils, residual, oil ash corrosion from, 601t
- Fume scrubber, polyester fiber glass, 635t
- Furnace linings, 10-92
- Fused-cast refractories, 10-92

**G**

Galvanic corrosion, aluminum aircraft oil cooler, 395t  
Galvanic couple test, 533t  
Galvanic current in carbonated beverage cans, 477t  
Galvanic experiments made to test suitability of steel weldments for parent metals, 2t

**GAS**

Atmosphere of, lag time on tin-plate steel affected by, 135t  
Feed and effluent, metals vs, 627t  
Methane-oxygen combustion, metals vs, 622t  
Sniff (chlorine), materials used for handling, 355t  
Transmission line, reconditioning and coating of, 279t  
Utilities industry, annual purchase of corrosion resistant materials by, 121t  
Wet and dry, inhibitors fogged with, 241t  
Gases, cell (chlorine), materials used for handling, 355t  
", high temperature, refractories for handling, 10-92  
Gaskets, chlorine mixtures vs materials used in, 355t  
Gasoline, inhibitors used in, 158t  
Gathering system for sour gas, design of, 413t  
Generator, gas, 622t  
Generators, steam, stress corrosion cracking of, 450t  
Girbotol unit, steel equipment in corrodes, 189t  
Glass, hydrogen fluoride vs, 541t  
", plate, impingement tests on, 10-92  
", tank, fused-cast refractory use of, 10-92  
Glass-lined steel vs chlorine mixtures, 355t  
Glass fiber reinforcement for coatings, 4-102  
Glass probe method of testing coatings, 12-93  
Glycol solutions in sour gas processing, 413t  
Glycol-water cooling system, aluminum alloy in, 395t  
Gold, titanium coupled with in HCl, 566t  
Gradient cell, use of, 644t  
Gradient test cell, cathodic protection requirements for lead cable sheath defined with, 389t  
Grain boundary segregation in aluminum bronze alloys, 295t  
Graphite anodes for ships, 581t  
Graphitic embrittlement of nickel tubing at high temperatures, 1-112  
Gravel surfacing in industrial roofing, 513t  
Greases, suitability of for aluminum-frame minesweepers, 403t  
Green salt process in uranium refining, 168t  
Grit blasting, steel prepared for painting by, 428t  
Grooving, HF alkylation units, 237t  
Gunite, offshore drilling structures coated with, 5-131  
", sour water strippers coated with, 358t  
Gypsum moulding plaster backfill, 497t

**H**

Hafnium, zirconium corrosion in HCl not affected by presence of, 103t

**H—Continued**

Hafnium-free zirconium, rate of dissolution and passivation of in HF, 286t  
Halides, pitting corrosion influenced by presence of, 25t  
Harbor corrosion problems, marine borers vs wood, 45t  
Hardness, effect of on accelerated testing of chromium steels, 269t  
", relation of to sulfide stress corrosion cracking of steel, 437t  
Hardness testing, oil well tubing evaluated by, 49t  
Hastelloy A and B, HCl vs in butane isomerization units, 85t  
Hastelloy C, chemical plant exposures vs, 341t  
Heat effects in steel weldment related to failure, 2t  
Heat exchanger, design of, 9-103  
", nickel tube shell components fall in, 1-112  
", nitric acid vs tubing of, 6-99  
", tubing for, 6-95, 6-99  
Heat flux conditions, determining corrosion rates under, 257t  
Heat recovery problems in nickel extraction plant, 4-95  
Heat-resistant alloys for use with residual fuels, 601t  
Heat-shock resistance of refractories, 10-92  
**HEAT TREATMENT**  
Alloys, 455t  
Aluminum-magnesium alloys, 337t  
Nickel tubing from heat exchangers, 1-112  
Stainless steel (Types 316 and 316L), 221t  
Stainless steel (200 and 300 series), 147t  
Steel alloys against sulfide corrosion cracking, 437t  
Valve seat ring (Type 316 SS) for water treating system, 1t  
Heating, metallurgical structures of wrought aluminum-magnesium alloys affected by, 55t  
Heterocyclic nitrogen compounds as corrosion inhibitors, 128t  
High film-build alkyls, application of, 171t  
High flow velocity loop, use of in dynamic aqueous systems, 179t  
High pressure gas wells, well completion practices in, 73t  
High pressure products pipe line, cathodic protection of, 12-104  
High resistivity soil, magnesium anodes in, 497t  
High strength steels, delayed failure of, 207t  
High temperature (See Temperature, high)  
High velocity loop, water stream in, 183t  
Hoods, polyester, fiber glass, 635t  
Hospital ware, carbon steel, steam resistant coatings for, 202t  
Hot spray coatings, Saran applied in shipyards, 3-116  
Hot spray vinyl coatings in refinery, 171t  
Hot vinyl prime, 642t  
Humidity, critical, for steel, 526t  
", principle of, 529t  
Humidity bath test of coatings, 12-93  
Hydrocarbon conversion system, 619t

**H—Continued****HYDROGEN**

Absorption of by steel during pickling, 135t  
Atmospheres containing vs metals, 627t  
Attack by in HF alkylation units, 237t  
Content of in tin plate steel influences lag time, 135t  
High strength steels, concentration of in, 207t  
Hydrogen sulfide determination in, 125t  
Stress corrosion cracking affected by, 9-103  
Hydrogen dislocation and stress corrosion cracking, 9-103  
Hydrogen effusion in dynamic aqueous systems, corrosion rate measurement by, 179t  
**HYDROGEN EMBRITTLEMENT**  
Bend test of for acetylenic alcohol concentration, 275t  
Cathodically protected steel, 591t  
High strength steel, 207t, 399t  
Oil well tubing subjected to, 49t  
Tubing steel, oil country, 437t  
Hydrogen evolution from Hf-free Zr in HF, 286t  
Hydrogen fluoride, air pollution from, 541t  
", glass vs, 541t  
Hydrogen fluoride in HF alkylation units, 237t  
Hydrogen peroxide vs iron, 526t

**HYDROGEN SULFIDE**

Air pollution from, 541t  
Aqueous, refinery equipment vs, 189t  
Cooling water in sour gas processing, presence of in, 413t  
Disposal of in refineries after water stripping, 358t  
Iso-corrosion rate curves for at high temperatures, 125t  
Nickel vs, 529t  
Oil well tubing subjected to, 49t  
Screening of inhibitors to reduce, 303t  
Water flooding problems complicated by, 307t  
Hydrogen sulfide-brine systems, stress corrosion cracking in, 437t  
Hydrogen sulfide-oil-brine mixtures vs steel, 299t, 303t  
Hydrogen sulfide-water mixtures, organic coatings tested in, 5-121  
Hydrogen swells in cans, 11-100  
Hydrometallurgical refining of nickel, 547t  
Hyperion ocean outfall, corrosion protection of, 363t  
Hypochlorite, titanium and zirconium resistance to, 341t

**I**

Identification of corrosion products on copper and its alloys, 199t  
Impedance characteristics of isolated aluminum oxide films, 283t  
Imperfection theory of pitting corrosion, 25t  
Impressed current, naval vessels protected with, 2-87  
", steel pipe sewer outfall in ocean protected with, 363t  
", use of in study of pitting corrosion, 25t  
Impingement tests on non-metallics, 10-92

**I—Continued****INCONEL**

Chemical plant exposures vs, 341t  
Cladding, welding of, 10-83  
High temperature vs, 619t  
High temperature gases vs, 622t  
Oil ash corrosion vs, 601t  
Resistance of in hydrofluorination reactor, 168t  
Index, numerical, abstract punch card, 254t  
India, metals testing in, 631t  
Indicators, use of in pitting corrosion studies, 25t  
Indium, titanium coupled with in HCl, 566t  
Industrial atmospheres, metals in, 533t  
", non-ferrous metals vs, 529t  
", steel vs, 526t  
", tin alloys in, 3-113  
Industrial corrosives, polyesters vs, 635t  
Industrial roof construction, 513t  
Influence of temperature on corrosion fatigue, 262t  
Information selector, photoelectric, 251t  
Inhibiting effects of phosphate on aluminum, 7t  
Inhibition of pitting corrosion on stainless steels, nitrates affect, 32t  
Inhibition of pitting corrosion with nitrates, 25t

**INHIBITORS**

Aluminum alloy corrosion in glycol-water reduced by, 395t  
Amines (filming) used on carbon steel sour water stripper components, 358t  
Anodic and cathodic, 455t  
Automobile anti-freeze, 607t  
Carbon tetrachloride-water vapor atmospheres, 447t  
Chromates to reduce cavitation attack, 269t  
Concrete reinforced with steel, suitability for, 382t  
Cooling water, 233t  
Evaluation from cathodic polarization measurements, 517t  
Filming amines in utility plant condensate systems, 8-99  
Fogging or flotation with, in tankers and storage tanks, 241t  
High pressure gas wells treated with, 73t  
Hydrogen sulfide attack of steel reduced with, 299t, 303t  
Inside a products pipe line, 131t  
Oil soluble, 241t  
Oil soluble for petroleum products pipe lines, 158t  
Organic, colloid, 455t  
", nitrogen compound, 128t  
", in petroleum refining industry, 321t  
Pickling operation, 275t  
Polyvalent ion-polyphosphate for cooling tower system treatments, 97t  
Recirculating cooling waters systems treated with, 20t  
Screening of for oil field equipment, 303t  
Secondary recovery, evaluation of, 307t  
Sour gas well corrosivity reduced with, 413t  
Sour naphtha lines, use on, 189t  
Stress corrosion cracking, 450t  
Tank ship, 557t  
Water dispersable, for tankers, 241t  
Water flood, 12-99



**I—Continued****INHIBITORS (Continued)**

- Water flood corrosion, screening of, 7-97
- Water soluble (sodium nitrite) for pipe lines, 158t
- XON-4, action of, 469t
- Inhibitor film persistence, 554t
- Inhibitors for acids used in chemical cleaning, 17t
- Inhibitor squeeze process, 554t
- Initiation and growth during pitting corrosion, theory of, 25t
- Injection water, oil well, 12-99
- Injection well tubing string, 413t
- Injection wells, 12-99
- Inorganic zinc silicate plus vinyl mastic system protects offshore drilling structures, 5-131
- Installation of anodes on offshore structures, 9-112

**INSTRUMENTS**

- Aluminum sub-surface corrosion measuring, 9-114
- Classical potentiostat for study of passivity, 369t
- DC corrosion meters with varistors to measure potentials in stray current areas, 68t
- Potential measuring device for pipe carrying sea water, 417t
- Ship hull potential measuring, 587t
- Soil corrosivity measuring device for field conditions, 77t
- Ultrasonic for tank ship corrosion-loss measurements, 561t
- Underground corrosion measurement, 571t
- Insulating materials, chloride stress corrosion cracking of austenitic stainless steel, 69t
- Insulation, deterioration on for duct anodes, 423t
- Interaction in analysis of variance, 83t

**INTERGRANULAR CORROSION**

- Aluminum-magnesium alloys at service temperatures, 55t
- Effect of sigma phase vs chromium carbides in Type 316 and 316L stainless steel, 221t
- Stainless steel (Type 316 and 316L), 213t
- " ", (200 and 300 series), 147t
- Type 302 stainless steel vessels in sulfuric-organic acid, 123t
- Valve seat ring, Type 316 SS, in water treating system, 1t
- Intergranular penetration corrosion of aluminum, 9t
- Internal cathodic protection of pipes carrying sea water, 417t
- Internal corrosion, inhibitors inside a products pipe line, 131t
- " ", products pipe lines, 158t
- " ", tank ships, 557t
- Internal oxidation of nickel chromium alloys, 194t
- Ion exchange theory of pitting corrosion, 25t
- Ions and molecules of Type XON-4 as inhibitors, 469t
- Ions in aqueous solution affecting uniform corrosion of aluminum, 9t
- IR drop method on ships, 587t
- Iridium, titanium coupled with in HCl, 566t

**IRON**

- Alloys containing vs molten boron oxide, 85t
- Atmospheric corrosion of, 526t

**I—Continued****IRON (Continued)**

- Cast, buried specimens of vs soils, 1-107
- " ", chlorine mixtures vs, 355t
- " ", erosion resistance of, 269t
- " ", molten salt vs, 257t
- Condensate cycle corrosion of, 8-99
- Hydrogen sulfide vs with respect to pH, 189t
- Inhibitors of Type XON-4 for, 469t
- Nickel chromium alloys containing, 194t
- Pure, HCl vs, 517
- Soft, corrosion fatigue of in sea water, 455t
- Stress corrosion cracking susceptibility of aluminum bronze alloys affected by content of, 295t
- Titanium coupled with in HCl, 566t
- Zirconium corrosion in HCl affected by content of, 103t
- Iron-containing rolled zinc, marine environments vs, 409t
- Iron content analysis, corrosion inhibitor efficiency in high pressure gas wells evaluated through, 73t
- Iron in source water, 12-99
- Iron phosphatizing, 508t
- Iron pick up in carbonated beverage cans, 477t
- Iso-corrosion rate curves for high temperature hydrogen-hydrogen sulfide, 125t
- Isobutane fractionating system, HF vs, 237t
- Isomerization units, butane, minimum corrosion for, 185t
- " ", nickel alloy lining for, 8-109

**J**

- J-55, oil well tubing composed of, 49t
- " ", stress corrosion cracking tests on, 437t
- Jackets, polyethylene, for steel pipe, 6-100
- Joints, field, on steel pipe in ocean, 363t

**K**

- Kel-F, steam resistance of, 202t
- Kerosene, inhibitor evaluation involving use of, 517t
- Kinetic constants for oxidation of aluminum, 13t
- Kinetic data in terms of oxidation mechanism on aluminum, 13t
- Kinetics of aqueous aluminum corrosion, 13t
- K-Monel vs HF, 237t
- Kyanite, converted, high temperatures vs, 10-92

**L**

- Labor force, efficiency of in pulp plant coating program, 488t
- Labor and materials costs in reconditioning underground steel pipe, 279t
- Laboratory methods, determining corrosion rates under heat flux conditions, 257t
- " ", identifying corrosion products on copper, 199t
- Laboratory tests for intergranular corrosion of austenitic stainless steels, 213t

**L—Continued**

- Lag time test for tin-plate steel, 135t
- Laminates, polyester fiber glass, physical properties of, 635t
- Leaching of chlorides onto metal surfaces, 69t
- Leaching, nickel refining by, 547t
- Leaching system in nickel extraction plant, 4-95

**LEAD**

- Cable sheaths, cathodic protection of, 389t, 423t, 644t, 9-116
- Electrode, field use of not recommended on cable sheath, 389t
- Linings, for nickel extraction plant equipment, 4-95
- Pickled panels affected by presence of, 275t
- Soils vs in burial tests, 1-107
- Titanium coupled with in HCl, 566t
- Lead-acid brick systems in chemical plants, 2-98
- Lead-silver alloy anodes for ships, 581t
- Lead sheathed telephone cable, 9-116
- Leather, sulfur dioxide vs, 541t
- Library, corrosion reference, 251t, 254t
- Light oil tanks, accelerated atmospheric corrosion of, 171t
- Limnoria vs wood, 45t

**LININGS**

- Exchanger tube, 627t
- Furnace, 10-92
- Miscellaneous, annual purchases of by industries, 121t
- Nickel alloy, in refinery isomerization unit, 9-109
- Plastic, for starch production service, 113t
- Pump, 473t
- Steel pipe, pretreatment prior to, 275t
- Tank, chemical resistant, 10-85
- " ", polyester, fiber glass, 635t
- Liners, clay-bonded silicon carbide, 10-92
- Liquid phase fuming nitric acid vs carbon steel AISI 1020, 245t
- Liquid phase butane isomerization, 185t
- Literature, metals corrosion articles recently published in CORROSION, abstracts of, 546t
- Literature survey, sigma phase vs chromium carbides of intergranular corrosion of 316 and 316L stainless steel, 213t
- Low temperature separation of sour gas, 413t

**M**

- M22 alloy (aluminum), electrode potential behavior of in phosphoric acid, 63t
- Macro-cells in corroding reinforced concrete, role of, 382t
- Macro-galvanic corrosion cell in reinforced concrete bridge, 331t
- Macro- and micro-corrosion cells, corrosivity of soil related to formation of, 77t

**MAGNESIUM**

- Aluminum alloyed with vs temperature, 55t
- Atmospheric corrosion of, 529t

**M—Continued****MAGNESIUM (Continued)**

- Cathodic protection of pipe lines with, 497t
- Milling system for, 8-105
- Soluble anodes of, 643t
- Stress corrosion cracking mechanism in alloy of, 7-106
- Magnesium anode/inhibitor spray system, tank ship, 557t
- Magnesium-1% manganese alloy anodes in NaCl electrolyte, 76t
- Magnesium sulfate, addition of to residual fuel oil, 601t
- Magnetic theory of pitting corrosion, 25t
- Magnetostrictive test for cavitation attack, 269t
- Maintenance, industrial roofing, 513t
- Maintenance coating program, pulp and paper plant, 488t
- Maintenance program, power plant, 7-107
- Management's role in pulp plant coating program, 488t
- Management, paint testing program involving, 503t
- Mandapam Camp, India, metals tested at, 631t
- Manganese, effect of in low phosphorous 0.3% copper steels, 533t
- Manganese phosphatizing, 508t
- Manganese alloyed with magnesium, anodes of exposed to NaCl electrolyte, 76t
- Manholes, telephone, drainage of, 9-116
- Marine atmospheres, metals in, 533t
- " ", reinforcing steel in concrete in, 382t
- " ", steel vs, 526t
- Marine boring organisms vs wood, 45t

**MARINE ENVIRONMENT**

- Carbon steel in offshore platform, 8-103
- " ", steel in sea water, 483t
- " ", vessels, naval, 2-87
- Coatings, offshore drilling structure, 5-131
- " ", ship bottom, 315t
- Electrical generating plants, 6-95
- Internal corrosion of tank ships, 557t
- Lead-silver alloy anodes for ship cathodic protection, 581t
- Metals tested in, 631t
- Non-ferrous metals in, 529t
- Organic coatings tested for use in tropics, 291t
- Pipe, cement mortar coated steel for sewer outfall vs, 363t
- Rubber-base paint used to protect transformer in, 1-111
- Steel in, 526t
- Steel reinforced concrete bridge vs, 331t
- Tank ship corrosion loss measurement, 561t
- Tin alloys in, 3-113
- Wooden hulled aluminum-frame minesweepers, design of for, 493t
- Zinc in, 409t
- Mask composition in chemical milling, 9-105
- Mastics, annual purchase of by industries, 121t
- Materials, pump, 473t
- Materials deterioration in polluted atmospheres, 541t

**M—Continued**

Materials of construction, nickel refining process, 547t

**MATERIALS SELECTION**

- Automobile, 167t
- Chemical milling process, 8-105
- Minesweeper, 403t
- Nickel-cobalt extraction plant, 4-95
- Oil field tubing, 437t
- Mean tide exposure of organic coatings in tropics, 291t
- Measurement, ship hull potentials, 587t
- " , tank ship corrosion losses, 561t
- " , underground corrosion, 571t
- " , underground electrical current, 576t
- Measurement of anchor pattern profile on grit blasted steel, 428t
- Mechanical fracture, distinguishing of from stress corrosion fracture, 399t
- Mechanical properties, oil well tubing, 49t

**MECHANISM**

- Action of  $XON^-$  inhibitors, 469t
- Aluminum alloy corrosion from copper deposition, 395t
- Aqueous aluminum corrosion, relation of to corrosion product film, 9t
- " , by use of kinetic data, 13t
- Aqueous hydrogen sulfide corrosion of steel, 189t
- Atmospheric corrosion of non-ferrous metals, 529t
- Carbon tetrachloride-water vapor vs mild steel, 447t
- Carbonated beverage can corrosion, 477t
- Cavitation attack, 269t
- Chloride stress corrosion cracking of austenitic stainless steel, 69t
- Corrosion fatigue of steels, 262t
- Ferrous metal corrosion in atmosphere, 526t
- Fuming nitric acid's role in corrosion of metals, 215t
- Inhibitors, oil soluble, 158t
- Magnesium alloy anodes dissolved in NaOH electrolyte, 76t
- Molten boron oxide vs high temperature alloys, 85t
- Oil ash corrosion, 601t
- Oil ash mixtures (synthetic) vs Type 310 stainless steel, 443t
- Oxidation resistance of stainless steel from silicon, 613t
- Passivation of hafnium-free zirconium in HF, 286t
- Pitting corrosion of metals, 25t
- Pitting corrosion of stainless steels, 39t
- Reinforcing steel in concrete in marine atmospheres, 382t
- Stress corrosion cracking, alpha aluminum bronze in ammonia and steam atmospheres, 295t
- " , AZ31 B magnesium, 7-106
- " , steel, austenitic stainless, 373t, 9-103
- Weldments, steel, corrosion in NaOH, 2t
- Zirconium, corrosion of in HCl, 103t
- Melaprene, transformers coated with, 1-111
- Mercury, ammonium nitrate storage tanks contaminated with, 6-99
- Metal treatment, steel reinforcing concrete in marine atmospheres, 382t

**M—Continued**

- Metal-alcohol coating, 275t
- Metal dusting, 619t, 622t, 627t
- Metal finishing plating solutions, polyesters vs, 635t
- Metals corrosion articles published recently in CORROSION, abstracts of, 546t
- Metals, foreign, effect of on titanium corrosion in boiling HCl, 566t
- Metallic cations, inhibitive effect obtained by addition of to cooling tower systems, 97t
- Metallic coatings vs fuel oil ash corrosion, 601t
- Metallurgical factors, pitting corrosion related to, 25t
- Meters, DC corrosion, potential measurements with in stray current areas, 68t
- Methane-oxygen combustion, attack on metals by synthesis gas from, 622t
- Micro-chemical identification of corrosion products on copper, 199t
- Mill scale, hydrogen embrittlement related to, 591t
- " , removal of from structures, 6-102
- Milling, chemical, material selection in, 8-105
- Mines, nickel, 547t
- Minesweepers, aluminum used in, 403t
- Minimum corrosion for butane isomerization units, 185t
- Mixed-base alloys, Multimet N-155 vs molten boron oxide, 85t
- Moa Bay Process, extraction of nickel by, 4-95
- Modified disc-heat flux technique, 257t
- Moisture, lag time on tin-plate steel affected by, 135t
- " , scaling of steels affected by, 141t
- " , steel reinforced concrete bridge vs, 331t
- Moisture penetration of concrete reinforced with steel, 382t
- Molding of chlorinated polyether, 11-108
- Molten metals, refractories for, 10-92

**MONEL**

- Atmospheric corrosion of, 533t
- Cast, erosion resistance of, 269t
- Chemical plant exposures vs, 341t
- High temperature gases vs, 622t
- HCl vs in butane isomerization units, 185t
- HF vs, 237t
- Sour water strippers of vs hydrogen sulfide, 358t
- Monel cable for magnesium anodes, 12-106
- Monoethanolamine inhibits carbon tetrachloride attack of mild steel, 447t
- Morpholine, glycol-water solutions containing, 607t
- Morpholine type inhibitor in sour gas processing system, 413t
- Morpholines, N-substituted, effect of on inhibition, 128t
- Moulds, casting of PVC in, 8-107
- Mullite brick, electric furnace, high temperatures vs, 10-92

**N**

- N-80, oil well tubing composed of, 49t
- " , stress corrosion cracking tests on, 437t

**N—Continued**

- N-substituted morpholines, effect of on inhibition, 128t
  - Naphtha, light crude, 189t
  - National Bureau of Standards research on underground corrosion, 45-year summary of, 1-107
  - Naval vessels, cathodic protection of, 2-87
  - Neoprene, pipe for underground service coated with, 7-101
- NICKEL**
- Atmospheric corrosion of, 529t, 533t
  - Graphically embrittled, recovery of, 1-112
  - High temperature gases vs, 622t
  - HCl vs in butane isomerization units, 185t
  - Hydrometallurgical refining of, 547t
  - Oil ash corrosion vs, 601t
  - Titanium coupled with in HCl, 566t
  - Nickel alloy lining in refinery isomerization units, 8-109
  - Nickel and nickel alloys, cladding of, 10-88
  - Nickel and stress corrosion cracking, 9-103
- NICKEL BASE ALLOYS**
- Hastelloy C for starch production service, 113t
  - Hastelloy R-235 vs molten boron oxide at 2052 F, 85t
  - Haynes Stellite No. 1 for corn oil processing equipment, 113t
  - Inco 702 vs molten boron oxide, 85t
  - Inconel vs molten boron oxide, 85t
  - Nimonic 75 vs molten boron oxide, 85t
  - Nickel chromium alloys, internal oxidation of, 194t
  - Nickel-cobalt extraction plant, materials in, 4-95
  - Nickel-copper alloys, atmospheric corrosion of, 533t
  - Ni-Resist, Type 1, hydrochloric acid vs, 185t
  - Nitrate additions, pit activity on stainless steels after, 32t
  - Nitrate concentration at various chloride levels, inhibitors related to, 450t
  - Nitrates, effect of on soft drink corrosivity, 11-100
  - " , pitting corrosion inhibited with, 25t
  - Nitric acid recovery system, corrosion of equipment in, 168t
  - Nitride-bonded silicon carbide shades, 10-92
  - Nitrogen, zirconium corrosion in HCl exposed to, 103t
  - Nitrogen compounds, organic, as inhibitors, 128t
  - Nitrogen dioxide, effect of on corrosion of AISI 1020 by fuming nitric acid, 245t
  - Non-destructive testing, inspection methods used in high pressure gas wells, 73t
  - Non-destructive thickness measurements on tank ships, 561t
  - Non-ferrous metals, atmospheric corrosion of, 529t
  - " , cladding of, 10-88
  - Non-reactive wash primers, 311t
  - Notch sensitivity, oil well tubing failure related to, 49t
  - Notch sensitivity effects in stress corrosion test on high strength steels, 399t
  - Notched specimens, stress corrosion cracking tests on, 437t
  - " , high strength steel, testing of, 207t

**N—Continued**

- Nylon, properties of, 11-108
  - Nylon rope for anodes, 12-106
- O**
- Offshore drilling structures, coatings for, 5-131
  - Offshore platform, carbon steel in corrodes, 8-103
  - Offshore structures, cathodic protection anodes on, 9-112
  - " , electrodes to check potentials on, 12-106
  - Oil additives, oil ash corrosion vs, 601t
  - Oil and gas well tubing, organic coatings for, 5-121
  - Oil ash, synthetic fuel, Type 310 stainless steel vs, 443t
  - Oil ash corrosion, 443t, 601t, 5-126
  - Oil-brine-hydrogen sulfide mixtures vs steel, 299t, 303t
  - Oil country tubular goods, stress corrosion cracking of, 437t
  - Oil refinery applications of thick-film synthetic coatings, 171t
  - Oil soluble inhibitors for product pipe lines, 131t, 158t
  - Ore, nickel, corrosion problems involving, 4-95
  - " , refining of, 547t
  - Ore refinery processing of uranium, 168t
  - Organic coated beverage cans, 477t
  - Organic coatings in tropical environments, 291t
  - Organic materials, polyethylene coating's resistance to, 117t
  - Organic nitrogen compounds as inhibitors, 128t
  - Organo-nitrile process vs Types 201, 202, 304 and 316 stainless steel, 147t
  - Organo-nitrogen compounds vs stainless steels (200 and 300 series), 147t
  - Organized studies, aluminum and aluminum alloys, electrochemistry of, 63t
  - Orthophosphate to reduce corrosivity of cooling tower water, 97t
  - Orthophosphates, cooling water systems treated with, 20t
  - Oscillographic method, aluminum in chlorides studied with, 63t
  - Outfall, ocean, corrosion protection of, 363t
  - Oxidation, chromium-nickel steels at high temperatures, 141t
  - " , high temperature, 622t
  - " , internal, of nickel chromium alloys, 194t
  - " , stainless steel at high temperatures, effect of silicon on, 613t
  - Oxidation process of aluminum in air and water, 13t
  - Oxide films, air-formed, on tin plate steel, 135t
  - " , on iron, 526t
  - " , on stainless steels at high temperatures, 613t
  - Oxidizing agents, polyethylene coating's chemical resistance to, 117t
- OXYGEN**
- Atmospheric, passivation by with  $XON^-$  inhibitors, 469t
  - Carbonated beverage can corrosion related to, 477t
  - Condensate at electrical utility plant, content of related to corrosivity of, 8-99
  - Dissolved, flood water containing, 307t
  - " , underground cables vs, 9-116
  - Exclusion of in canning, 11-100
  - High temperature water systems affected by, 183t
  - Influence of on corrosion, 455t

**O—Continued****OXYGEN (Continued)**

- Soft drink corrosiveness related to, 11-100
- Underground corrosion stimulated by, 1-107
- Oxygen concentration, corrosion fatigue of steels related to, 262t
- Oxygen content, weldment corrosion rate related to, 2t
- Oxygen diffusion rate in soil influences corrosivity of soil, 77t
- Oxygen reduction in pitting corrosion, 25t
- Oxygen scavengers, tests with on inhibitors, 450t
- Ozone and photo-chemical smog, 541t

**P**

- Pack-calorized materials, 622t
- Packing glands, pump, 473t
- Paint program, pulp plant, 488t
- Paint testing program, engineering approach to, 503t

**PAINTS**

- Aluminum cooling tower components, use on, 20t
- Anti-corrosive for aluminum exposed to sea water, 403t
- Anchor pattern profile, effect of on performance of, 428t
- Automobile, 167t, 511t
- " , air pollution of, 541t
- Hydrogen sulfide vs, 541t
- Moisture on reinforced concrete bridges reduced by, 331t
- Rubber base transformers coated with, 1-111
- Selection of for chemical resistance, 10-85
- Ship hull, 587t
- Underwater metal surfaces coated with, 335t
- Zinc-rich vs sea water, 409t
- Palladium, titanium containing, 644t
- " , titanium coupled with in HCl, 566t
- Paper plant, coatings in, 488t
- Paper, sulfur dioxide vs, 541t

**PASSIVATION**

- Aluminum alloys in acid media, 63t
- Austenitic stainless steel surfaces in chlorides, 69t
- Carbon steel in fuming nitric acid, 245t
- Hafnium-free zirconium in HF, 286t
- Steel in concrete, factors affecting, 382t
- Zirconium in HF, 286t
- Passivity, classical potentiostat used in study of, 309t
- Pearson Null Bridge, 571t
- Pearson null circuit potential break curve, 576t
- Penetration theory of pitting corrosion, 25t
- Peptization theory of pitting corrosion, 26t
- Perchlorate ion, pitting tendencies of with stainless steels, 32t
- Pertechnetate ion as an inhibitor, 469t
- Petroleum refining industry, annual purchase of corrosion resistant materials by, 121t

**P—Continued**

- pH, aluminum alloy behavior in chlorides affected by, 63t
- " , effect of on corrosion, 455t
- " , flood water corrosivity related to, 307t
- " , iron in hydrogen sulfide, corrosion of related to, 189t
- " , metallic lead cathodic protection requirements vary with, 389t
- " , water, aluminum corrosion in related to, 9t
- Phenol formaldehyde, testing of for oil well tubing coating, 5-121
- Phenolic wastes, removal of from refineries, 358t

**PHENOLICS**

- Baked, tubing in condensate and high pressure oil wells protected with, 49t
- Catalyst-cured, refinery application of, 171t
- Catalyzed, epoxy, 642t
- Modified, steam resistance of, 202t
- Tropical environments vs, 291t
- Phosphate treated water, 492t
- Phosphates, aluminum corrosion in water inhibited with, 7t, 9t
- " , coatings of on mild steel sterilizer shells, 202t
- " , cooling waters inhibited with, 233t
- Phosphatizing treatments, 508t
- Phosphorylated lecithin solutions, reactive coatings from, 508t
- Photoelectric information selector, 251t
- Physical properties of polyethylene coatings, 117t
- Pickling and dipping solutions, polyesters vs, 635t
- Pickling bath, pretreatment with prior to lining steel pipe, 275t
- Pilot plant testing, refinery equipment for processing nickel, 547t
- Pin holes, can, 11-100

**PIPE**

- Asbestos-cement, underground corrosion vs, 1-107
- Bare, cathodic protection of, 417t
- Red brass, stress corrosion cracking of, 433t
- Steel, cathodically protected, low temperature bend testing of, 591t
- " , injection systems, 12-106
- " , pickling bath for prior to lining, 275t
- " , polyethylene jackets for, 6-100
- " , sea water holding, cathodic protection of, 417t
- " , underground coatings for, 7-101
- " , evaluating economy of reconditioning and coating, 279t

**PIPE LINES**

- Bridge caulking technique in, 3-118
- Cathodic protection of in high resistivity soil, 497t
- Petroleum products, 158t
- Product, inhibitor testing inside, 131t
- Soil corrosivity toward, 77t
- Steel, effect of velocity on with sulfuric acid, 326t
- Submarine, steel, sewage disposal, 363t

**P—Continued**

- Piperidine, effect of on inhibition, 128t
- Piping, industrial structure, coating of, 6-102
- Pit growth in stainless steels, 32t
- Pit inertia and pit memory on stainless steels, 32t
- Pit interaction in study of pit growth on stainless steels, 32t
- Pit measurement on tankers, 557t

**PITTING**

- Aluminum 52S in glycol-water, 395t
- Atmospheric corrosion test specimens, 533t
- Copper tubing for recirculated water, 492t
- Corrosion fatigue of steels related to, 262t
- Evaluation of paints in terms of, 503t
- HF alkylation units, 237t
- High temperature alloys in molten boron oxide, 85t
- Metals in glycol-water solution, 607t
- Stainless steel, an electrochemical study of, 32t, 39t
- " , austenitic, in chlorides, 69t
- " , (Type 310), exchanger tubing of, 627t
- " , soot-blower tube of, 622t
- Steel, Type 316 ELC, 547t
- Zirconium in HCl, 103t
- Pitting corrosion, critical analysis of, 25t
- Pitting distribution and locl, 25t

**PLASTICS**

- Chlorinated polyether, properties and uses of, 11-108
- Coatings for offshore drilling structures, 5-131
- Corn wet milling industry equipment protected from acids by use of, 113t
- Epoxy liner for field joints of steel pipe in ocean, 363t
- Linings of, annual purchases of by industries, 121t
- Organic coatings for oil well tubing, testing of, 5-121
- Organic coatings in tropical environments, 291t
- Polyester fiber glass equipment, 635t
- Polyethylene jackets for steel pipe, 6-100
- Pump linings, 473t
- Reinforced, sprayed resins and fibers in, 12-106
- Rigid or reinforced, annual purchases of by industries, 121t
- Steam resistant coatings for carbon steel hospital ware, 202t
- Tank trucks reinforced with, 2-94
- Thermosetting resins (reinforced) vs chlorine, 355t
- Thick-film synthetic coatings, oil refinery applications of, 171t
- Tubing for high pressure gas wells protected by coatings with, 73t
- Underground coatings of, 7-101
- Plastic cell test to evaluate water flood corrosion inhibitors, 7-97
- Plastic deformation and crystal growth, 9-103
- Plastic film method in tank ship corrosion measurements, 561t

**P—Continued**

- Plastic rope for anodes, 12-106
- Plastisols, polyvinylchloride, application of, 8-107
- Plating, tin-zinc, 3-113
- Platinum anodes for ships, 581t, 596t
- Platinum coupled with titanium in HCl, 566t
- Plugging tendencies of flood water, 12-99
- Polarization current, measurement of, 571t
- Polarization measurements, cathodic inhibitor evaluation from, 517t
- Polarization measurements in stainless steel pitting corrosion study, 39t
- Polluted atmospheres, 541t
- Polyamid, oil well tubing coating of, 5-121
- Polybischloromethyl oxetane, properties of, 11-108
- Polyester fiber glass equipment, 625t
- POLYESTERS**
- Industrial corrosives vs, 635t
- Metal finishing plating solutions vs, 635t
- Pickling and dipping solutions vs, 625t
- Reinforced, highway tank trucks using, 2-94
- Stripping solutions for salvage vs, 635t
- Polyethylene, coating resistance of to acids and alkalies, 117t
- " , jackets of for steel pipe, 6-100
- " , rope of for anodes, 12-106
- " , tapes of for underground pipe, 7-101
- Polyposphates, addition of to cooling waters, 20t
- Polysulfide elastomers, underground pipe protection with, 7-101
- Polysulfides, bolt caps filled with, 6-95
- POLYVINYL CHLORIDE**
- Chlorine environments vs, 355t
- Piping of vs chemical attack, 8-105
- Plastisols, application of, 8-107
- Sheet, plasticized, for modified starch service, 113t
- Tapes, for underground pipe, 7-101
- Polyurethane, oil well tubing coated with, 5-121
- Polyurethane coatings, properties of, 12-93
- Polyurethane tube coatings, 4-100
- Potassium dichromate as a hydrogen sulfide inhibitor, 303t
- Potassium fluoride, rate of dissolution of Zr in HF affected by, 286t
- Potential measuring device on pipe, design of, 417t
- Potential profiles, 576t
- Potential studies used in pitting phenomena study, 25t
- Potential-time curves of Zr in HF, 286t
- Potentials, anode-to-hull, 587t
- " , pH vs for lead, in cathodic protection of cable sheath, 389t
- " , zirconium in HF, 286t
- Potentiometer, commercial portable null, 571t
- Potentiometer-voltmeter, 571t
- Potentiostat, classical, application of to study of passivity, 369t



**P—Continued**

- Power plant, coatings engineer's role in design and planning of, 7-107
- "", electrical generating, 6-95
- Preheater exchanger, tube failure in, 627t
- Preheater tubing, deterioration of, 627t
- Pressure, high, organic coatings tested at for oil well tubing, 5-121
- Pretreatment prior to lining steel pipe, 275t
- Prime, hot vinyl, 642t
- Primers, aluminum alkyd paint used over blast cleaned steel, 428t
- "", rubber-base paints applied with for transformers, 1-111
- "", wash, 311t, 315t
- "", ship bottom, 315t
- Probability, stress corrosion cracking of copper alloys, 433t
- Process equipment, cathodic protection of, 123t
- Processing, chemical, 200 and 300 series stainless steels in, 147t
- Products pipe line, cathodic protection of, 12-104
- "", inhibitors inside, 131t
- "", oil soluble inhibitors for, 158t
- Program, coating and lining selection, 10-85
- "", maintenance coating for pulp and paper plant, 488t
- "", paint testing, 503t
- Properties needed in offshore drilling structure coatings, 5-131
- Pulp and paper, maintenance coating program in plants of, 488t
- "", industry, annual purchases of corrosion resistant materials by, 121t
- Pump and valve material, chlorine vs, 355t
- Pumps, design and materials for, 473t
- Pumps, iron, flood waters vs, 12-99
- Punch cards, NACE abstract, 251t, 254t
- "", photoelectric selector for, 251t

**Q**

- Quantitative measurement of pitting attack, 25t
- Questionnaire replies, corrosion in HF alkylation units, 237t
- "", material for handling chlorine mixtures, 355t

**R**

- R alloy (aluminum), electrode potential behavior of in phosphoric acid, 63t
- Racks, atmospheric corrosion testing, 533t
- Radioactive tracers, leaks in bonded lead lined vessels located with, 2-98
- Rain, atmospheric, corrosion test panels exposed to, 533t
- "", non-ferrous metals corrosion related to, 529t
- Rate-of-pickling on tin-plate steel, 125t
- Rate of solution movement, influence of on corrosion, 455t
- Reactive coatings, 508t

**R—Continued**

- Reactive wash primers, 311t
- Reactors, low purity water used in, 83t
- Recirculating coolant tests, 395t
- Reconditioning and coating underground steel pipe, 279t
- Records and reports of pulp plant maintenance coating program, 488t
- Recovery of graphitically embrittled nickel, 1-112
- Rectifiers, on ships, 581t
- "", products pipe line, 12-104
- Redox probe field technique, 335t
- Refinery, inhibition of cooling water in, 233t
- "", nickel alloy lining for isomerization unit, 8-109
- "", oil, thick-film synthetic coatings in, 171t
- "", sour water stripper corrosion in, 358t
- Refinery equipment, aqueous hydrogen sulfide vs, 189t
- Refining, nickel, 547t
- "", petroleum, organic inhibitors for, 321t
- Refining industry, butane isomerization units, 185t
- "", HF alkylation units, 237t
- Refining of uranium, corrosion problems in, 168t
- Refractories, special corrosion resistant, 10-92
- Regenerator, copper liquor, 547t
- Reinforced concrete bridge, inhibiting attack of steel in, 331t
- Reinforced polyesters for highway tank trucks, 2-94
- Reinforcement, glass fiber for coatings, 4-102
- Reproducibility of atmospheric corrosion test results, 533t
- Residual fuel, oil ash corrosion problems in, 443t, 601t, 5-126
- Residues attack chemical distilling column, 11-99
- Resins, polyester, 635t
- "", sprayed, 12-106
- "", thermosetting, reinforced, chlorine mixtures vs, 355t
- Resonance type instruments for tank ship corrosion loss measurement, 561t
- Rhodium, titanium in HCl exposed to, 566t
- Rigid plastisols, 8-107
- Ringworm corrosion, oil well tubing attacked by, 49t
- Rivets, coating of, 6-102
- Roof construction and maintenance, industrial, 513t
- Rope, plastic, for anode suspension, 12-106
- Rotational casting of plastisols, 8-107
- Rotrode technique on reactive coatings, 508t

**RUBBER**

- Air pollutants vs, 541t
- Natural, steel vessels lined with for sodium hypochlorite service, 113t
- Silicone, underground pipe protected with, 7-101
- Synthetic, 643t
- "", tropical sea water vs, 291t
- Urethane, new formulations give versatility to, 4-100
- Rubber base coatings, steam resistance of, 202t
- Rubber base paints, transformers protected with, 1-111

**R—Continued**

- Rubber linings, annual purchases by industries, 121t
- Rubberized asphalt mastic coatings for offshore structures, 5-131
- Rust, types of on polished steel, 526t
- Rusting, internal can surfaces, 11-100

**S**

- S2 alloy (aluminum), electrode potential behavior of in phosphoric acid, 63t
- SAFETY**
- In chemical cleaning, 17t
- Polyethylene coating application related to, 123t
- Sour gas condensate production, methods of achieving in, 413t
- Toxicity of boiler deposits, 5-126
- Salinity of atmospheres, metals corrosion related to, 631t

**SALT**

- Concentration of on oil well steel, 299t
- Concentration of on reinforcing steel in concrete, 382t
- Content, steel reinforced concrete bridge affected by, 331t
- Sea, deposits of on ferrous metals, 526t
- Solutions, lead for cable sheath tested in, 389t
- Solutions, titanium and zirconium resistance to, 341t
- Salt crack testing of polyethylene, 6-100
- Salt spray cabinet test on reinforcing steel in concrete, 382t
- Salt water (see Water, salt)
- Salt-fog, resistance of rubber-base paint to, 1-111
- Salts, neutral, influence of on corrosion, 455t
- "", polyethylene coating chemical resistance to, 117t
- Sand blasted steel, anchor patterns on, 428t
- Saran, hot spray application of in shipyards, 3-116
- Scale, cargo tank removal of, 557t
- "", outer oxide, on stainless steel, 613t
- "", removal of by acids, 17t
- "", removal of from steel pipe, 275t
- Scale deposits, HCl used in removal of from steel, 69t
- Scale inhibitors for cooling water, 233t
- Scales, inner oxide, on stainless steel, 613t
- Scales on steels (Types 302, 309 and 330), 141t
- Scaling, chromium-nickel steel, 141t
- Scanning device, photoelectric for corrosion data, 251t
- Scraper trap deposits, pipe line, 131t
- Scrapers, pipe line, 158t
- Screening effects in pitting corrosion, 25t
- Screening of inhibitors, chloride stress corrosion, 450t
- "", oil well equipment, 303t
- "", water flood corrosion, 7-97
- Screening tests for chemical resistant coatings, 10-85
- Screening test for inhibitor film persistence, 554t

**S—Continued**

- Screens, filter, pipe line, 131t
- Screw shell failure from stress corrosion cracking, 433t
- Scrubbing tower, steel fogging type, lead-acid brick used to relime, 2-98
- Search systems, corrosion data, 251t
- Sea water (see Water, salt)
- Secondary recovery, inhibitors for evaluated, 307t
- Sediment, inhibitors for pipe lines evaluated by measuring of, 158t
- Sensitizing, stainless steels, 200 and 300 series, 147t
- "", cladding, 10-88
- Service life, industrial roofing, 513t
- "", sulfuric acid pipe lines, relation of to velocity, 326t
- Severe environments, rubber-base transformer finish used in, 1-111
- Sheath, lead, telephone cable, 9-116
- Shelter, atmospheric corrosion test racks having, 533t
- Sheltered and open tests, metals in India, 631t
- Shepard's cane, earth resistivity measurements with, 571t
- Sherritt Gordon Mines, nickel refining at, 547t
- Ships, cathodic protection of, 339t, 403t, 483t, 557t, 581t, 596t, 2-87
- "", coatings for bottoms of, 315t
- "", coatings for hulls of, 483t
- "", tank, 561t, 557t
- "", wooden-hulled aluminum-frame minesweepers, 403t
- Shipyards, hot spray application of Saran in, 3-116
- Sigma phase, effect of on intergranular corrosion of Type 316 and 316L stainless steel, 221t
- "", in Types 316 and 316L stainless steel, 213t
- Silica, accumulation of at metal/scale interface for chromium-nickel steels, 141t
- Silicon, aluminum alloys affected by trace elements of, 63t
- "", compounds of added to residual fuel oil, 601t
- "", high temperature oxidation of steel affected by content of, 613t
- "", nickel chromium alloys containing, 194t
- Silicon carbide, refractories of, 10-92
- Silicon iron anode in ducts to protect cable, 423t
- Silicone rubbers, underground pipes coated with, 7-101
- Silicones, steam resistance of, 202t
- Silt, ducts containing, 423t
- "", recirculating water system having, 492t
- Silver, titanium coupled with in HCl, 566t
- Skin temperatures, Type 316 stainless steel, 257t
- Slag, inclusions of in welding, 2t
- "", molten, metals vs, 10-92
- "", oil-fired boilers containing, 5-126
- "", steel tubes accumulate on heating of vanadium compounds, 443t
- Slurries, abrasive, in pumps, 473t
- Slurry, nickel powder, 547t
- Slush moulding of plastisol parts, 8-107
- Smog, photo-chemical, 541t
- Smoke, air pollution from, 541t
- Sodium, oil ash corrosion related to presence of, 5-126
- Sodium benzoate, inhibition of anti-freezes with, 607t

**S—Continued**

- Sodium carbonate, air pollution from, 541t
- Sodium chloride, anodes of AZ 63 and Mg-1% Mn alloy vs, 76t
- " ", steel wires have corrosion fatigue in, 262t
- " ", stressed austenitic stainless steels vs, 373t
- Sodium dichromate, pitting reduced by addition of, 269t
- Sodium dinonylnaphthalene, anti-freezes containing, 607t
- Sodium fluoride, rate of dissolution of Zr in HF affected by addition of, 236t
- " ", titanium-platinum couples in HCl containing, 566t
- Sodium hydroxide, nickel tubing vs, 1-112
- Sodium hypochlorite vs natural rubber linings, 113t
- Sodium metasilicate, anti-freezes inhibited with, 607t
- Sodium nitrate for steel as chloride stress corrosion inhibitor, 450t
- Sodium nitrate, anti-freeze inhibition with, 607t
- Sodium nitrite as inhibitor in products pipe lines, 153t
- Sodium pyrophosphate as a hydrogen sulfide inhibitor, 303t
- Sodium silicate, inhibition of anti-freezes with, 607t
- Sodium sulfate, oil ash corrosion related to, 601t
- Sodium sulfate-vanadium pentoxide mixture vs Type 310 stainless steel, 443t
- Sodium sulfite for steel as chloride stress corrosion inhibitor, 450t
- Sodium tetrasilicate plus sodium tetraborate, corrosion of aluminum in glycol-water inhibited by, 395t
- Soft drinks, effect of copper on corrosiveness of, 11-100

**SOIL**

- Cathodically protected steel in, 591t
- Corrosivity classification system for, 77t
- Corrosivity of measured, 77t
- Corrosivity of to buried metals, 1-107
- Electrical measurements in, 576t
- High resistivity, cathodic protection of pipe lines in, 497t
- Lead vs, 389t
- Specific resistivity of measured, 77t
- Soil resistivity, instruments for measuring, 571t
- " ", survey of, 497t
- Solid particulates in air pollution, 541t
- Solvents, polyurethane coatings vs, 12-93
- Soot blower tubes, 622t
- Sorting machine, photoelectric, 251t
- Sound velocity, tank ship corrosion loss measurements involving, 561t
- Sour gas condensate production, 413t
- Sour water strippers, corrosion in, 358t
- Sour-crude immersion, polyurethane coatings tested by, 12-93
- Snow, cathodic protection of products pipe line in, 12-104
- Spalling of reinforced concrete in marine atmospheres, 382t
- Spectrographic examination of corrosion products on copper, 199t

**S—Continued**

- Spot tests on polyurethanes, 12-93
- Spraying, metal, oil ash corrosion vs, 601t
- Stability limits of metals in solid solutions, 455t
- Stable static potential, obtaining of on lead electrode, 389t
- Stack, polyester, fiber glass, 635t
- Staining, internal, can surface, 11-100
- Starch granules, abrasive action vs hard rubber and phenolic resins, 113t
- Static electrode potential behavior of aluminum alloys, 63t
- Static water drop test, nitrogen compound inhibitors evaluated by, 128t
- Statistical analysis, cracking susceptibility variables in oil country tubing, 437t
- " ", low purity water as a corrosion factor in nuclear reactor cooling systems, 83t
- Steam, oil soluble inhibitors fogged with, 241t
- " ", stress corrosion crack paths of alpha aluminum bronze in atmosphere of, 295t
- Steam generators, stress corrosion cracking of, 450t
- Steam resistant coatings for carbon steel hospital ware, 202t
- Sterilizers, steam resistant coatings for, 202t

**STEEL**

- Alloy, buried specimens of vs soils, 1-107
- AOI 5LX-52, pipe sewer outfall composed of for use in ocean, 363t
- Cathodic protection of in sea water, 483t
- Cathodically protected, hydrogen embrittlement of, 591t
- Chlorine mixtures vs, 355t
- Chromium, accelerated cavitation of related to hardness, 269t
- " (0.5 percent), hydrogen sulfide iso-corrosion curves for, 125t
- Chromium-low nickel-manganese, for chemical manufacturing processes, 147t
- Cold rolled, physical properties of, 635t
- Concrete bridge reinforced with, 331t
- Copper, low phosphorous, effect of manganese in, 533t
- Galvanized, atmospheric corrosion of, 409t
- Grit blasted, paint performance on, 428t
- High phosphorous, atmospheric corrosion of, 533t
- High strength, delayed failure of, 207t
- " ", stress corrosion and hydrogen embrittlement tests on, 399t
- Inhibitor evaluation on in acidic environments, 321t
- Marine atmosphere vs, 526t
- Milling systems for, 8-105
- N-80, hydrogen embrittlement of, 591t
- Nickel (low), oil well tubing composed of, 49t
- Oil-brine-hydrogen sulfide mixtures vs, 299t, 303t
- Pompton and Utica, corrosion fatigue of, 262t

**S—Continued****STEEL (Continued)**

- Reinforcing in concrete in marine atmospheres, 382t
- SAE 1010, iron phosphate coatings on, 508t
- Spring (1095), fruit cutter blade of, 6-100
- Structural, coatings of, 6-102
- " ", fracture of, 591t
- " ", power plants use, 6-95
- Sulfur dioxide vs, 541t
- Tin coated for foods, 11-100
- Tin-plate, factors influencing rate-of-pickling test on, 135t
- Type 422, net fracture stress of vs temperature, 399t
- Type 446, high temperature gases vs, 622t
- Type XON-4 inhibitors to protect, 469t

**STEEL, ALLOY (LOW)**

- Atmospheric corrosion vs, 533t
- Industrial atmospheres vs, 526t
- Oil well tubing composed of, 49t
- Tank ships, use on, 557t
- Weldments of vs NaCl, 2t

**STEEL, CARBON**

- Filters of, 547t
- HF vs, 237t
- High temperature vs, 619t
- High temperature gases vs, 627t
- High temperature water systems vs, 183t
- Liquid-phase fuming nitric acid vs, 245t
- Low, cooling waters vs, 233t
- Low, hydrogen effusion rates on, 179t
- Offshore platforms of corrode, 8-103
- Sour water vs in refineries, 358t
- Steam resistant coatings for hospital ware composed of, 202t
- Sulfuric acid-containing pipe lines of, 326t
- Weldments of vs NaCl, 2t

**STEEL, MILD**

- Carbon tetrachloride vs, 447t
- Chemical plant exposures vs, 341t
- Corrosion of in India, 631t
- Ethylene glycol vs, 607t
- HCl vs, 517t
- In 73% caustic, cathodic protection of, 123t
- Inhibitor fogging and flotation with coupons of, 241t
- Light naphtha process equipment using, 189t
- SAE 1010, cooling tower water vs, 97t

**STEEL, STAINLESS**

- 200 and 300 series in chemical manufacturing processes, 147t
- Aluminum-frame minesweepers having components of, 403t
- Ammonium nitrate stored in, 6-99
- Atmospheric corrosion of, 533t
- Cast, erosion resistance of, 269t
- Cladding of, 10-88
- Effect of cathodic reaction on pitting behavior of, 25t
- Chromium-nickel (18-8) vs aldehydes, organic acids, organic esters, chlorides, sulfates, and organo-nitrogen compounds, 147t

**S—Continued****STEEL, STAINLESS (Continued)**

- Chromium-nickel, high temperature oxidation of, 141t
- Electrochemical study of pitting corrosion in, 32t, 39t
- Industrial atmospheres vs, 526t
- Nickel refinery equipment of, 547t
- No. 20 alloy, sulfuric and sulfurous acids vs, 113t
- Pit growth in when exposed to ferric chloride, 32t
- Pitting corrosion of, 25t
- Polarization measurements in when exposed to ferric chloride, 39t
- Type 330, oxidation of, 141t
- Silicon's effect on high temperature oxidation of, 613t
- Uranium refining process vs, 168t

**STEEL, STAINLESS, AUSTENITIC**

- Chloride stress corrosion cracking of, 69t
- High temperature oxidation of, 141t
- Hydrogen sulfide iso-corrosion curves for, 125t
- Stress corrosion cracking of, 373t, 9-103
- Type 302, cathodic protection of in sulfuric-organic acid, 123t
- " ", oxidation of, 141t
- Type 302B, dehydrogenation process headers of, 619t
- " ", high temperature vs, 619t
- Type 304, nitric acid vs, 257t
- " ", sulfurous acid fumes vs, 113t
- " ", oxidation of at 2000 F, 141t
- Type 310, dehydrogenation process catalyst tubes of, 619t
- " ", high temperature vs, 619t
- " ", hot gases vs, 622t
- " ", molten boron oxide vs, 85t
- " ", synthetic fuel oil ash vs, 443t
- " ", tubing deterioration of, 627t
- Type 316, high temperature vs, 619t
- " ", in 77% H<sub>3</sub>PO<sub>4</sub> at various skin temperatures, 257t
- " ", sour water strippers of vs hydrogen sulfide, 358t
- " ", stress corrosion cracking of, 336t
- " ", sulfur dioxide vs, 113t
- " ", valve seat rings of fail in water treating system, 1t
- Type 316 and 316L, intergranular corrosion of, 213t, 221t
- Types 316 and 317, phosphoric acid vs, 351t
- Type 321, high temperature vs, 619t
- Type 347, high temperature vs, 619t
- " ", hot gases vs, 622t
- " ", stress corrosion cracking of, 450t
- Vs aldehydes, organic acids, organic esters, chlorides, sulfates and organo-nitrogen compounds, 147t
- Steel-tin beverage cans, 477t
- Steel and copper compounds in aluminum cooling towers, 20t
- Steel cable for magnesium anodes, 12-106
- Steel piping, water tower, 492t
- Steel wires, corrosion fatigue of, 262t

**S—Continued**

Storage, canned goods, 11-100  
 ", nitric acid and ammonium nitrate, 6-99  
 Stray currents, underground structures vs, 455t  
 ", underground corrosion related to, 1-107  
 Stray current areas, DC corrosion meters used in, 68t  
 Strength, high tensile, materials for, 10-88  
 Stress, high tensile, steel specimens vs, 207t, 591t

**STRESS CORROSION CRACKING**

Alpha aluminum bronze in ammonia and steam atmospheres, 295t  
 Aluminum vs, 455t  
 Aluminum bronze alloys, wrought, 101t  
 Aluminum-magnesium alloys, 55t, 337t  
 Ammonium nitrate storage tanks, 6-99  
 Copper alloys, 433t  
 In HF alkylation units, 237t  
 Inhibitors screening to prevent, 450t  
 Mechanism of in AZ 31B magnesium alloy, 7-106  
 Oil country tubular goods, 437t, 646t  
 Oil well tubing, 49t  
 Steels, high strength, 399t

**STRESS CORROSION CRACKING, STEELS, STAINLESS**

200 and 300 series for chemical manufacturing processes, 147t  
 Austenitic, in chlorides, 69t, 373t, 9-103  
 ", Type 316 ELC tank, 547t  
 ", Type 316 tubes in corn syrup evaporator, 113t  
 Strippers, sour water, 358t  
 Stripping solutions for salvage, polyesters vs, 635t  
 Structural design plus coatings, 6-102  
 Structure-to-soil potentials, 576t  
 Submarine test cable, use of with steel pipe line in ocean, 363t  
 Sub-surface corrosion of aluminum, field measurement of, 9-114  
 Sugar and syrup production, materials of construction for, 113t  
 Sulfate ion, pitting tendencies of with stainless steels, 32t  
 Sulfates, stainless steels (200 and 300 series) vs, 147t  
 Sulfated orange oxide vs metals, 168t  
 Sulfide corrosion cracking of steels, heat treatment used against, 437t  
 Sulfide ions, hydrogen embrittlement of steel related to, 591t  
 Sulfide precipitation of nickel and cobalt, 547t  
 Sulfides, cooling water contaminated by, 547t  
 ", removal of from refinery waters, 358t  
 Sulfite, oil ash corrosion intensified by, 5-126  
 Sulfur, canned goods containing, 11-100  
 ", iron containing, atmospheric corrosion of, 526t  
 ", residual fuel oils containing, 601t  
 Sulfur content of fuel related to oil ash corrosion, 5-126

**S—Continued**

Sulfur dioxide, atmospheric corrosion of non-ferrous metals by, 529t  
 ", atmospheric corrosion of iron by, 526t  
 Sulfur dioxide and trioxide, air pollution from, 541t  
 Sulfur pollution, non-ferrous metals exposed to, 529t  
 Sulfurous compounds, accelerated corrosion of zinc by, 533t  
 Suppliers, pulp plant coating, 488t  
 Surface finishing, cavitation attack related to, 269t  
 ", Types 201 and 202 stainless steel, 147t

**SURFACE PREPARATION**

Aluminum cooling towers for painting, 20t  
 Anchor pattern profile affects paint performance, 428t  
 Carbon steel for exposure to fuming nitric acid, 245t  
 Polyethylene coating use related to, 117t  
 Pulp plant, 488t  
 Refinery metal for thick-film coatings, 171t  
 Wash primers, connection of with, 311t  
 Surface preparation for painting, 503t  
 Surface treatment, stainless steel (Type 309), 141t  
 ", steam resistant coating effectiveness influenced by, 202t  
 ", steel pipe prior to lining, 275t  
 ", zirconium corrosion rate in HCl affected by, 103t  
 Surge protection cell, 497t  
 Synergized polyphosphate treatments in cooling tower systems, 97t  
 Synthesis gas, attack on metals by from methane-oxygen combustion, 622t  
 Synthetic coatings, thick-film, oil refinery applications of, 171t  
 Synthol process, metals deterioration in, 627t  
 Sweet corrosion cracking of oil field tubing, 437t

**T**

Tank ships, inhibitors for, 241t  
 ", internal corrosion of, 557t  
 ", measuring corrosion loss on, 561t  
 Tank trucks, highway, reinforced polyesters for, 2-94  
**TANKS**  
 Coal tar lined, 12-99  
 Linings for, 10-85  
 Polyester fiber glass, 635t  
 Stainless steel (Type 316 ELC), stress corrosion cracking of, 547t  
 Storage, inhibitors for, 241t  
 ", coating of, 6-102  
 Tantalum, platinum clad anodes of for ships, 596t  
 Tantalum resistance to calcium chloride, 341t  
 Tapes, annual purchases of by industries, 121t  
 ", plastic, underground corrosion of pipe combatted with, 7-101  
 Tar system lines, HF vs, 237t  
 Teflon, steam resistance of, 202t

**T—Continued**

Telephone cables, differential aeration of, 9-116

**TEMPERATURE**

Aluminum-magnesium alloys vs, 337t  
 Critical, high temperature alloys in molten boron oxide, 85t  
 Influence of on corrosion fatigue, 262t  
 Influence of on corrosion rate, 455t  
 Low, bend test of cathodically protected steel pipe, 591t  
 Oil well tubing tested for effect of, 49t  
 Service, influence of on wrought aluminum - magnesium alloys, 55t  
 Zirconium corrosion rate in HCl affected by, 103t

**TEMPERATURE, HIGH**

Aluminum-magnesium alloys at, 55t  
 Attack on metals by synthesis gas from methane-oxygen combustion, 622t  
 Corrosion in a hydrocarbon conversion system, 619t  
 Corrosion product films on aluminum, 7t  
 Determining of corrosion rates under heat flux conditions, 257t  
 Graphitic embrittlement of nickel heat exchanger tubing, 1-112  
 Hydrogen effusion measurement in dynamic aqueous systems, 179t  
 Intergranular corrosion of Type 316 and 316L stainless steel, 213t  
 Iso-corrosion rate curves for hydrogen-hydrogen sulfide, 125t  
 Metal deterioration in atmospheres containing carbon monoxide and hydrogen, 627t  
 Molten boron oxide vs alloys, 85t  
 New bonding process gives added versatility to cladding, 10-88  
 Nickel-chromium alloys, internal oxidation of, 194t  
 Nitric acid vs heat exchanger tubing, 6-99  
 Oil ash corrosion problems, 443t, 601t, 5-126  
 Organic coatings tested at for oil well tubing, 5-121  
 Oxidation of chromium-nickel steels, 141t  
 Silicon's effect on oxidation of stainless steel at, 613t  
 Special corrosion resistant refractories, 10-92  
 Type 310 stainless steel vs synthetic fuel oil ash (in laboratory), 443t  
 Water, system of, 183t  
 Temperature dependence on time in aqueous corrosion of aluminum, 13t  
 Temperature differential in heat exchangers, 6-99  
 Temperature inversion, air pollution related to, 541t  
 Tensile strength, high temperature alloy, change of in molten boron oxide, 85t  
 Tensile testing of atmospheric corrosion test specimens, 533t  
 Teredo vs wood, 45t

**T—Continued**

Testing, atmospheric corrosion, procedures employed in, 533t  
 ", cladding materials, 10-88  
 ", long and short term, zirconium in HCl, 103t

**TESTING, LABORATORY**

Aluminum and alloys by repetitive oscillographic method, 63t  
 Aluminum in water, 9t, 13t  
 Aluminum-magnesium alloys at service temperatures vs stress corrosion cracking, 55t  
 Anchor pattern profile relation to paint performance on steel, 428t  
 Automobile anti-freeze inhibitors, 607t  
 Behavior of construction materials for minesweepers, 403t  
 Carbonated beverage can perforation, 477t  
 Cathodic protection, lead cable sheath, 389t  
 ", mild steel in 73% caustic, 123t  
 ", steel pipe carrying sea water, 417t  
 Cavitation-erosion of materials, 269t  
 Chemical and solvent resistance of polyurethane coatings, 12-93  
 Coatings for chemical plants, 10-85  
 Coatings, ship bottom, 315t  
 Cooling tower system inhibitors evaluated, 97t  
 Copper condenser tubes for water treatment, 492t  
 Corrosion fatigue, influence of temperature on, 262t  
 Criteria for cathodic protection of steel in sea water, 483t  
 Determining of corrosion rates under heat flux conditions, 257t  
 Die casting alloys vs detergent solutions, 327t  
 Effect of silicon on high temperature oxidation of stainless steel, 613t  
 Fuming nitric acid vs AISI 1020, 245t  
 High temperature corrosion product films on aluminum, 7t  
 High temperature oxidation of chromium-nickel steels, 141t  
 HCl vs austenitic stainless steel, 69t  
 Hydrogen embrittlement of cathodically protected steel, 591t  
 Hydrogen sulfide at high temperatures vs steels, 125t  
 Hydrogen sulfide inhibitor effectiveness, 303t  
 Impedance characteristics of isolated aluminum oxide films, 283t  
 Inhibitor evaluation from cathodic polarization measurements, 517t  
 Inhibitor film persistence, 554t  
 Inhibitor fogging and flotation, 241t  
 Inhibitors, aluminum glycol-water cooling system, 395t  
 ", carbon tetrachloride - water vapor (for mild steel), 447t  
 ", cooling water, 233t  
 ", secondary recovery, evaluation of, 307t  
 Intergranular attack of austenitic stainless steels, 213t



**T—Continued****TESTING, LABORATORY**  
(Continued)

- Intergranular corrosion of Type 316 and 316L stainless steel, 221t
- Materials selection for dehydrogenation process catalyst tubes, 619t
- N-80 and low alloy materials in 5% NaCl plus carbon dioxide, 49t
- Nickel-chromium alloys oxidized in air, 194t
- Oil ash (synthetic fuel) vs Type 310 stainless steel, 443t
- Oil-brine-hydrogen sulfide mixtures vs steel, 299t
- Organic coatings for oil well tubing, 5-12t
- Organic inhibitors for petroleum refining, 321t
- Organic nitrogen compounds as inhibitors, 128t
- Paint systems for chemical plants, 503t
- Phosphoric acid vs Types 316 and 317 stainless steel, 351t
- Pickling bath inhibitors for steel pipe, 275t
- Pit growth in 18-8 stainless steel exposed to ferric chloride, 32t
- Platinum for active ship anodes, 596t
- Polarization measurements for study of pitting corrosion in stainless steel exposed to ferric chloride, 39t
- Polyesters vs industrial corrosives, 635t
- Polyethylene jackets for steel pipe, 6-100
- Rates of dissolution and passivation of Hf-free Zr in HF, 286t
- Reactive coatings thickness measurement, 508t
- Reinforcing steel in concrete vs salt spray, 382t
- Screening tests of inhibitors to prevent chloride stress corrosion, 450t
- Steam resistant coatings for carbon steel hospital ware, 202t
- Steels, high strength (4340), effect of hydrogen concentration on, 207t
- Stress corrosion crack paths in alpha aluminum bronze, 295t
- Stress corrosion cracking, Az 31B magnesium alloy, 7-106
- " " " " N-80 and J-55, 437t
- " " " " stainless steel, austenitic, in chloride waters, 373t
- " " " " steel, Type 422, 399t
- Tin plate steel, lag time of determined, 135t
- Titanium and zirconium resistance to calcium chloride, alkali solutions, chlorine, hypochlorite, sulfuric acid, nitric acid, HCl and NaCl, 341t
- Weldments, carbon and low alloy steel, NaCl vs, 2t
- Wrought aluminum bronze alloys, stress corrosion cracking susceptibility of, 101t
- Zirconium vs HCl at atmospheric pressure, 103t

**TESTING, ON LOCATION**

- Aluminum sub-surface corrosion, 9-114
- Atmospheric corrosion of metals, 533t
- Cathodic protection, steel pipe carrying sea water, 417t

**T—Continued****TESTING, ON LOCATION**  
(Continued)

- Coatings for chemical plants, 10-85
- Criteria for cathodic protection of steel in sea water, 483t
- Element spacing in duct anodes for cables, 423t
- Filming amines vs iron and copper in condensate cycle, 8-99
- Inhibition of low temperature hydrogen sulfide corrosion in pipe still, 189t
- Inhibitor fogging and flotation, 241t
- Inhibitors, cooling water, 233t
- " " " " product pipe line, 131t, 153t
- Materials for butane dehydrogenation process, 619t
- Materials for gas generator-waste heat boiler, 622t
- Metals in tropical marine environments, 631t
- Monel, Inconel, steel, aluminum and copper corrosion rates in water reclaimer tower, 358t
- Organic coatings in tropical environments, 291t
- Paint systems for chemical plants, 503t
- Phosphoric acid vs Types 316 and 317 stainless steel, 351t
- Platinum anodes for active ships, 596t
- Polyesters vs industrial corrosion, 635t
- Screening inhibitors for water flood corrosion prevention, 7-97
- Soil corrosivity, 77t
- Soils vs buried metals and coating materials, 1-107
- Steam resistant coatings for carbon steel hospital ware, 202t
- Steels, stainless (200 and 300 series) for chemical processing, 147t
- Sweet corrosion cracking of copper, 437t
- Uranium refining process vs metals corrosion, 168t
- Zinc in marine environments, 409t
- Textiles, ozone vs, 541t
- " " " " sulfur dioxide vs, 541t
- Theoretical concepts of pitting corrosion, 25t
- Thermal conductivity of refractories, 10-92
- Thermal convection loop, use of in aqueous dynamic systems, 179t
- Thermocouple wires, molten boron oxide vs, 85t
- Thermoplastics, properties and uses of, 11-108
- Thick-film synthetic coatings in oil refinery applications, 171t
- Thickness, tank ship plate, measurement of, 561t
- Tin, titanium coupled with HCl, 566t
- Tin alloys in atmospheric exposure, 3-113
- Tin-nickel alloy resistance, 3-113
- Tin plate, staining of, 11-100
- Tin plate steel, rate of pickling on, 135t
- Tin-steel on carbonated beverage cans, 477t
- Tin sulfide on cans, 11-100

**T—Continued****TITANIUM**

- Alloys containing vs molten boron oxide, 85t
- Chemical plant exposure of, 341t, 643t
- Dissolution rate of in HF, 286t
- HCl vs, 566t
- Milling system for, 8-105
- Nickel-chromium alloys containing, 194t
- Platinum clad anodes of for ships, 596t
- Tubing in nickel extraction plant, 4-95
- Titanium and stainless steel pumps, 473t
- Topography, air pollution related to, 541t
- Tower footings, transmission, 6-95
- Towers, water treatment, 492t
- Toxic hazards in chemical cleaning, 17t
- Toxicity of boiler deposits, 5-126
- Transformers, rubber-base paint coatings on, 1-111
- Treatment of water, 492t
- Triethylenetetramine as a hydrogen sulfide inhibitor, 303t
- Tropical environment, metals tested in, 631t
- " " " " performance of organic coatings in, 291t
- " " " " synthetic rubbers and vinyls in, 643t
- Trusses, steel, coating of, 6-102
- Tube sheets, nitric acid vs, 6-99
- Tubes, 27-chrome alloy, high temperature vs, 619t
- " " " " urethane coatings for, 4-100

**TUBING**

- Aluminum, on minesweepers, 403t
- Copper, water, stress corrosion cracking of, 433t
- " " " " water tower, silt deposits on, 492t
- Nickel, heat exchanger, graphitic embrittlement of, 1-112
- Nipple tests, 12-99
- Oil and gas well, organic coatings for, 5-121
- Oil well, mechanical properties of, 49t
- Preheater, Type 310, determination of, 627t
- Sour gas well, resistance of, 413t
- Special alloy, high pressure gas wells protected with, 73t
- Stainless steel (Type 310), synthetic oil ash vs, 443t
- Tubular goods, oil country, stress corrosion cracking of, 437t
- Tubular heat flux corrosion tests, 257t
- Turbines, filming amines used to protect, 8-99
- " " " " gas, treatment of residual oil in, 601t
- Turbine oil test (ASTM), 321t
- Turbine type rust tests on inhibitors, 131t

**U**

- Ultrasonic measurement of tank ship losses, 561t
- Undercoating for marine atmospheres, 3-113
- Underground cable, differential aeration on, 9-116

**U—Continued**

- Underground corrosion, 576t
- " " " " cathodically protected steel, 591t
- " " " " duct anodes protect cables from, 423t
- " " " " instruments for measuring, 571t
- " " " " piping, 547t
- " " " " plastics and synthetic elastomers for coatings, 7-101
- Summary of 45-year Nat Bur of Standards research on, 1-107
- Underground structures, 68t, 455t
- Underwater metal surfaces in fresh water, 335t
- Uranium, corrosion problems in refining of, 168t
- Urethane, coatings of, new formulations for, 4-100
- " " " " properties of, 12-93
- " " " " steam resistance of, 202t
- Utility plant condensate system, filming amines control corrosion in, 8-99
- V**
- Vacuum annealing, zirconium corrosion rate in HCl affected by, 103t
- Vacuum bonding process, 10-88
- Vacuum tube millivoltmeter (DC), 571t
- Valve seat rings fail in water treating system, 1t
- Valves, chlorinated polyether, pressure temperature ratings of, 11-108
- Valves, chlorine mixtures vs, 355t
- Vanadium, oil ash corrosion resulting from, 443t, 601t, 5-126
- " " " " titanium coupled with in HCl, 566t
- Vanadium-containing fuels, oil ash corrosion problems with, 601t
- Vanadium pentoxide, oil ash corrosion from, 601t, 5-126
- Vanadium pentoxide-sodium sulfate mixtures vs Type 310 stainless steel, 443t
- Vapor condensation condition, stress corrosion of austenitic stainless steels in chloride waters during, 373t
- Vapor phase butane isomerization, 185t
- Variables in paint testing, 503t
- Variable interaction: a statistical solution, 83t
- Varistors, DC corrosion meters used with, 68t
- Velocity, steel pipe line life in sulfuric acid affected by, 326t
- " " " " water treatment system affected by, 492t
- Velocity problems, steel suitability for handling chlorine mixtures in terms of, 355t
- Vibratory method, erosion resistance of alloys determined by, 269t
- Vinyl chloride, unplasticized, properties of, 11-108
- Vinyl mastic coating for offshore drilling structures, 5-131
- Vinyl prime, hot, 642t
- Vinyl resin, testing of for oil well tubing coating, 5-121
- Vinyls, properties of, 12-93
- " " " " steam resistance of, 202t
- " " " " tropical environments and sea water vs, 291t, 643t

**V—Continued**

Visual observations on water stream in high temperature velocity loop, 183t  
 Voltmeter, dual sensitivity, 571t  
 ", moving coil deflection, 571t  
 ", portable DC vacuum tube, 571t  
 ", potentiometer, 571t

**W**

Wagner's analysis of cathodic protection compared with operating data for ships, 339t  
 Wash primers, development and characteristics of, 311t  
 " ", components of, 508t

**WATER**

Aluminum alloys in cooling towers vs, 20t  
 Anode installations in to protect product pipe lines, 12-104  
 Chloride containing, austenitic stainless steels in, 9-103  
 " ", stress corrosion of austenitic stainless steels in, 373t  
 Circulating, corrosion by, 492t  
 Color of in loop streams, 183t  
 Cooling, 233t, 413t, 417t, 547t, 9-103  
 ", chlorides in, 9-103  
 ", inhibition of, 233t  
 Deionized, aluminum alloys vs, 13t  
 ", nuclear reactor fuel element jacketing corroded by, 83t  
 Distilled, inhibitor screening tests in for aluminum protection, 395t  
 Effect of in corrosion of AISI 1020 in fuming nitric acid, 245t  
 Fresh, cathodic protection of naval vessels in, 2-87  
 ", organic coatings in tropics tested in, 291t  
 ", ship bottom coatings vs, 315t  
 High purity, aluminum alloys in, 7t  
 Hot, boehmite formed on aluminum in presence of, 283t  
 Low purity, nuclear reactor fuel element jacketing corroded by, 83t  
 Polyurethane coatings vs, 12-93  
 Soil corrosivity measured by chemical analysis of, 77t  
 Stress corrosion cracking of copper alloys in, 433t

**W—Continued****WATER (Continued)**

Stripped, disposal of in refineries, 358t  
 Tap and distilled vs aluminum, 9t  
 Tap, distilled and sea: chemical resistance of polyethylene coatings to, 117t  
 Tap, nuclear reactor fuel elements jacketing corroded by, 83t  
 Underground telephone cables exposed to, 9-116  
 Urethane coatings exposed to, 4-100

**WATER, SALT**

Carbon steels vs on offshore platforms, 8-103  
 Cathodic protection of naval vessel in, 2-87  
 Cathodic protection of steel in, 483t  
 Cathodic protection of steel pipes carrying, 417t  
 Cement mortar coated steel pipe sewer outfall vs, 363t  
 Coatings for ship bottoms vs, 315t  
 Concrete reinforced with steel vs, 382t  
 Inhibitors for use in, 241t  
 Organic coatings tested in presence of in tropics, 291t  
 Platinum anodes in for active ships, 596t  
 Power generating plants affected by, 6-95  
 Wooden hulled aluminum-frame minesweepers vs, 403t  
 Ships vs, 581t, 587t  
 Titanium and zirconium resistance to, 341t  
 Water flood operation involving, 12-99  
 Weldments, steel, testing of in, 2t  
 Zinc exposed to, 409t  
 Water absorption of acidic gases from hydrocarbons in refineries, 385t  
 Water boxes of condensers suffer graphitization, 6-95  
 Water condensate tank vs chlorides, 69t  
 Water drainage of telephone cable conduits, 9-116  
 Water flood, inhibitors for secondary recovery, 307t  
 " ", inhibitors screened for prevention of corrosion by, 7-97  
 Water flooding, corrosion control practices in, 12-99

**W—Continued**

Water pollution, electrical generating plant, 6-95  
 " ", elimination of in refineries, 358t  
 Water quality tests, 12-99  
 Water reclaiming towers, inhibitor injection into, 358t  
 Water stream in elevated temperature high velocity loop, 183t  
 Water treatment, 547t  
 " ", in aluminum cooling towers, 21t  
 " ", inhibitors for water cooling tower systems, 97t  
 " ", system, valve seat ring (Type 316 SS) fails in after 9 months, 1t  
 " ", test facility, four-tower, 492t  
 Water vapor, atmospheres containing carbon tetrachloride, inhibitors for, 447t  
 " ", non-ferrous metals exposed to, 529t  
 " ", non-ferrous metals vs, 529t  
 Waterproofing of industrial roofing, 513t  
 Wax coating for underground steel pipe, 278t  
 Weather, air pollution related to, 541t  
 ", atmospheric corrosion testing related to, 533t  
 Weather conditions, metals corrosion in India related to, 631t  
 Weld decay, HF alkylation units, 237t  
 Weld splatter, removal of, 6-102  
 Welding, cost of on underground steel pipe, 279t  
 ", phosphoric acid vs stainless steel samples subjected to, 351t  
 ", Types 316 and 316L stainless steel, effect on, 221t  
 Welding clad plate, 10-88  
 Welding practices on industrial structures, 6-102  
 Welding techniques related to fracture of steel weldments, 2t  
 Weldments, steel, NaCl solution vs, 2t  
 Welds, zirconium, corrosion rates of in HCl, 103t  
 Wellhead chokes, failure of in sour gas production, 413t

**WELLS**

Gas, high pressure, well completion and corrosion control in, 73t  
 Oil, inhibitors for secondary recovery, 307t  
 ", polyurethane coatings for equipment used in, 4-100  
 ", water flood operation of, 12-99

**W—Continued****WELLS (Continued)**

Sour condensate, tubing for, 49t  
 Sour gas, 413t  
 Sour oil, tubing for, 49t  
 Sweet oil, tubing for, 49t  
 Well completion and corrosion control of high pressure gas wells, 73t  
 Wetting units, reinforced concrete bridge protected with, 331t  
 Wire and sheet, relative corrosion rates of, 533t  
 Wood, aluminum used with on minesweepers, 403t  
 ", marine boring organisms vs, 45t  
 Wrought aluminum magnesium, alloys of vs temperature, 55t

**X**

XON-4 inhibitors, action of, 469t  
 X-ray diffraction, oxide films on stainless steel studied by, 613t

**Z****ZINC**

Atmospheric corrosion of, 529t  
 Corrosion of in India, 631t  
 Detergent solutions vs, 327t  
 Inhibitive effects of synergized polyphosphate increased by addition of, 97t  
 pH of in solutions determines corrosion rate of, 455t  
 Tin as undercoat on, 3-113  
 Titanium coupled with in HCl, 566t  
 Zinc chromate, aluminum box painted with for exposure to sea water, 403t  
 Zinc chromate primer, 508t  
 Zinc in marine environments, 409t  
 Zinc lead silicate for offshore drilling structures, 5-131  
 Zinc oxide, wash primer pigment replaced with, 508t  
 Zinc phosphatizing, 508t  
 Zinc spray, offshore drilling structures protected with, 5-131  
 Zinc tetraoxochrome-polyvinyl butyral primer, reactive coatings of on steel, 508t  
 Zinc-pigmented coating inside tank ships, 557t

**ZIRCONIUM**

Chemical plant exposure of, 341t, 643t  
 Hafnium-free, rates of dissolution and passivation of in HF, 286t  
 HCl vs at atmospheric pressure, 103t  
 Sodium and potassium hydroxides vs, 103t  
 Titanium coupled with in HCl, 566t

# Alphabetical Author Index

CORROSION, Technical and Technical Topics Sections, Volume 15, 1959

## A

- Aldimov, G. V.**  
Factors Influencing Corrosion .....455t
- Allen, E. R. Jr.**  
Discussion—Simple Screening Test for Determination of Inhibitor Film Persistence...556t
- Alexander, A. L.**  
Performance of Organic Coatings in Tropical Environments, with B. W. Forgeson and C. R. Southwell .....291t
- Discussion—Controlling Internal Corrosion of Tank Ships.....560t
- Discussion .....643t
- Andrews, C. R.**  
See Roller, David.....85t
- Anderson, E. A.**  
Zinc in Marine Environments.409t
- Anderson, Thomas F.**  
See Barnett, Robert E.....635t
- Anderson, W. A.**  
See Dix, E. H., Jr.....55t
- Discussion .....338t
- Annamalai, P. L.**  
See Rajagopalan, K. S.....631t
- Aziz, P. M.**  
Mechanism by Which Non-Ferrous Metals Corrode in the Atmosphere, with H. P. Godard.....529t
- Discussion—Observation on the Mechanisms and Kinetics of Aqueous Aluminum Corrosion.....642t

## B

- Backensto, E. B.**  
Iso-Corrosion Rate Curves for High Temperature Hydrogen-Hydrogen Sulfide—A Contribution to the Work of NACE Technical Group Committee, T-8, with J. W. Sjöberg. Publication 59-10.....125t
- Ballard, D. A.**  
Justification and Economics Engineering Approach to a Paint Testing Program, with V. B. Volkening.....503t
- Barnard, K. N.**  
Service Experience with Lead-Silver Alloy Anodes in Cathodic Protection of Ships, with G. L. Christie and D. G. Gage.....581t
- Barnett, Robert E.**  
Polyester Fiber Glass Equipment, with Thomas F. Anderson.....635t
- Barusch, M. R.**  
Control of Internal Corrosion of Petroleum Products Pipelines with Oil Soluble Inhibitors, with L. G. Haskell and R. L. Piehl.....158t
- Baskette, L.**  
Solving Corrosion Problems at Electrical Generating Plants .....6-95
- Beck, F. H.**  
See Staehle, R. W.....373t
- Behn, D. R.**  
Discussion—Corrosion in Sour Water Strippers.....362t
- Bell, E. G.**  
See Bobalek, E. G.....202t
- Belue, M. W., Jr.**  
Planning a Maintenance Coating Program for a Pulp and Paper Plant.....488t

## B—Continued

- Benes, Richard**  
Corrosion in the Corn Wet Milling Industry, with Fred J. Holsinger and Russell E. Pierson.....113t
- Bennett, G. A. (Cdr.)**  
Electrical Bonding of Cathodically Protected to Unprotected Ships, with N. S. Dempster and A. J. Wallace.....587t
- Berman, L. U.**  
See Schwogler, E. J.....128t
- Bigos, Joseph**  
Anchor Pattern Profile and Its Effect on Paint Performance .....428t
- Bishop, Claude R.**  
Discussion—Corrosion Resistance of Titanium and Zirconium in Chemical Plant Exposures.....644t
- Bloom, M. C.**  
See Krulfeld, M.....179t
- See Waldron, L. J.....2-87
- Bobalek, E. G.**  
Evaluation of Steam Resistant Coatings For Carbon Steel Hospital Ware, with W. R. R. Park, E. G. Bell and W. R. Dawson.....202t
- Boggs, James E.**  
See Shannon, Donald W.....299t
- See Shannon, Donald W.....303t
- Bowen, H. C.**  
Variable Interaction: A Statistical Solution, with C. Groot and J. L. Jaech...83t
- Brady, James M.**  
Advantages of Reinforced Polyesters for Use on Highway Tank Trucks.....2-94
- Brasher, D. M. (Miss)**  
Classification of Topics Relating to Corrosion.....254t
- Bregman, J. I.**  
Developments in Cooling Tower System Treatments (Part I—Polyvalent Ion-Polyphosphate Inhibitors), with T. R. Newman.....97t
- Brink, E. G.**  
Discussion—Corrosion Resistance of Titanium and Zirconium in Chemical Plant Exposures.....643t
- Discussion—Planning A Maintenance Coating Program for a Pulp and Paper Plant.....491t
- Brooks, W. B.**  
Mechanisms and Some Theoretical Aspects of Stress Corrosion Cracking of Austenitic Stainless Steels..9-103
- Brown, B. F.**  
Notch Sensitivity Effects in Stress Corrosion and Hydrogen Embrittlement Tests on High Strength Steels .....399t
- Brown, J. R.**  
Evaluation of Protective Coatings for Ship Bottoms..315t
- Brown, John R.**  
Discussion—Mechanical Properties and Corrosion Resistance of Oil Well Tubing .....53t
- Brown, Roy W.**  
Potentialities and Applications of Special Corrosion Resistant Refractories, with H. G. Noble .....10-92

## B—Continued

- Bruckner, W. H.**  
Cathodic Protection of Lead Cable Sheath, with Ole G. Jansson.....389t
- Studies on the Susceptibility of Cathodically Protected Steel to Hydrogen Embrittlement, with K. M. Myles...591t
- Discussion .....644t-646t
- Buck, Roger III**  
Effects of Foreign Metals on Corrosion of Titanium in Boiling 2M Hydrochloric Acid, with Billy W. Sloope and Henry Leidheiser, Jr.....566t
- Bundy, Alfred D.**  
Discussion—Some Properties and Uses of Chlorinated Polyether .....11-110
- Burns, Donald L.**  
Discussion—Corrosion in Sour Water Strippers .....362t
- Burd, Byron B.**  
Discussion—The Corrosion of Zirconium in Hydrochloric Acid at Atmospheric Pressure .....112t
- Calkins, K. W.**  
Corrosion Inhibitors for Carbon Tetrachloride—Water Vapor Atmospheres, with R. W. Hawley.....447t
- Caplan, D.**  
High Temperature Oxidation of Chromium-Nickel Steels, with M. Cohen.....141t
- Carr, D. M.**  
Five Case Histories on Corrosion Problems in Nitric Acid and Ammonium Nitrate Production and Storage .....6-99
- Cartledge, G. H.**  
Action of the  $XO_4^-$  Inhibitors .....469t
- Caterson, Alan G.**  
Discussion—The Corrosion of Zirconium in Hydrochloric Acid at Atmospheric Pressure .....112t
- Caughy, R. H.**  
See Hoyt, W. B.....627t
- Cessna, J. C.**  
Electrical Resistance Method for Studying Corrosion Inhibitors in Automotive Anti-Freezes .....607t
- Chinn, W. K.**  
See Rogers, T. H.....430t
- Chittum, Joe**  
Discussion—Stress Corrosion Cracking of Oil Country Tubular Goods .....646t
- Discussion—Corrosion Control Practices in the Wilmington Water Flood Operation...12-102
- Christie, G. L.**  
See Barnard, K. N.....581t
- Christofferson, DuWayne**  
Discussion—Oil Refinery Applications of Thick-Film Synthetic Coatings.....642t
- Clarke, John M.**  
Discussion—Design and Materials for Reduced Pump Corrosion.....476t
- Cohen, M.**  
See Caplan, D.....141t

## C—Continued

- Comeaux, Roy V.**  
Corrosion of Refinery Equipment by Aqueous Hydrogen Sulfide—A Contribution to the Work of Group Committee T-8 on Refining Industry Corrosion. Publication 59-12 .....189t
- Compton, K. G.**  
Instruments for Measurements in Underground Corrosion Work .....571t
- Condry, James T.**  
See Johnson, Wayne A.....9-112
- Cook, A. R.**  
Discussion—Controlling Internal Corrosion of Tank Ships.....560t
- Cook, W. B.**  
See Maier, R. W.....171t
- Copenhagen, W. J.**  
See Lewis, D. A.....382t
- Copson, H. R.**  
Some Experiments on Internal Oxidation of Nickel Chromium Alloys, with F. S. Lang.....194t
- Principles and Procedures Employed in the Design and Interpretation of Atmospheric Corrosion Tests .....533t
- Corely, John J.**  
Discussion—Wash Primer Development and Characteristics .....314t
- Cornet, I.**  
Influence of Temperature on Corrosion Fatigue, with Simcha Golan.....262t
- Costanzo, F. E.**  
Discussion .....335t
- Craig, H. Lee, Jr.**  
Discussion—Stress Corrosion Cracking of Oil Country Tubular Goods .....646t
- Craig, W. G.**  
See Lammon, J. C.....513t
- Creed, S. H.**  
Corrosion Keeps Knife Sharp on Fruit Canning Machine...6-100

## D

- Daly, J. J., Jr.**  
See Koehler, E. L.....477t
- Can Corrosion Problems...11-100
- Davis, Gordon**  
Bridge Caulking Technique Helps Solve Aerial Pipeline Crossing Problem .....3-118
- Davis, R. A.**  
New Bonding Process Gives Added Versatility to Cladding .....10-88
- Davis, Robert L.**  
Discussion—Methods of Installing Cathodic Protection Anodes for Offshore Structures .....12-106
- Dawson, W. R.**  
See Bobalek, E. G.....202t
- Dean, Mills III**  
Discussion—Principles and Criteria for Cathodic Protection of Steel in Sea Water—A Review .....487t
- Dean, Roy O.**  
Equivalent Electrical Circuit Analogy of Structure-To-Soil Potentials .....576t



## D—Continued

- DeBoer, F. E.**  
Discussion—Impedance Characteristics of Isolated Aluminum Oxide Films....643t
- Degnan, T. F.**  
Effect of Velocity on Life Expectancy of Steel Pipelines in Commercial Strengths of Sulfuric Acid.....326t
- De Lorenzo, John F.**  
Nickel Alloy Lining Cuts Costs in a Refinery Isomerization Unit.....8-109
- Dempster, N. S.**  
Corrosion of Aluminum Alloy in Glycol-Water Cooling Systems.....395t  
See Bennett, G. A.....587t
- Dexter, George T.**  
Discussion—New Bonding Process Gives Added Versatility to Cladding....10-90
- Dial, Roy E.**  
Discussion—Potentialities and Application of Special Corrosion Resistant Refractories.10-92
- Dillon, C. P.**  
Discussion—Failure of Type 316 Stainless Steel Autoclave Components.....336t
- Dillon, R. L.**  
Observations on the Mechanisms and Kinetics of Aqueous Aluminum Corrosion (Part 2—Kinetics of Aqueous Aluminum Corrosion).....13t  
Discussion.....336t  
Discussion.....642t
- Dix, E. H., Jr.**  
Influence of Service Temperature on the Resistance of Wrought Aluminum-Magnesium Alloys to Corrosion, with W. A. Anderson and M. Byron Shumaker.....55t  
Discussion.....338t
- Dravnieks, A.**  
Discussion—Iso-Corrosion Rate Curves for High Temperature Hydrogen-Hydrogen Sulfide.126t  
Discussion—Mechanism of Stress Corrosion of Austenitic Stainless Steels in Chloride Waters.....381t  
Discussion—An Industrial Experience of Attack on Metals by Synthesis Gas from Methane-Oxygen Combustion.626t
- Eberle, F.**  
An Industrial Experience of Attack on Metals by Synthesis Gas from Methane-Oxygen Combustion, with R. D. Wylie.....622t
- Ebling, H.**  
Discussion—Comparative Corrosion Resistance of 200 and 300 Series Stainless Steels in Chemical Manufacturing Processes.....155t
- Eddy, L. C.**  
Discussion—Cathodic Protection of Lead Cable Sheath.....644t
- Edwards, K. N.**  
Acetylenic Alcohol-Inhibited Pickling Bath as a Pretreatment Prior to Lining Steel Pipe, with L. J. Nowacki and E. R. Mueller.....275t
- Ellis, Wayne P.**  
Discussion—Filming Amines Control Corrosion in Utility Plant Condensate System..8-103
- Engle, J. P.**  
Chloride Stress Corrosion Cracking of the Austenitic Stainless Steels—A Contribution to the Work of NACE Task Group T-8A on Chemical Cleaning, with G. L. Floyd and R. B. Roseme Publication 59-5.....69t
- Evans, Dwight J.**  
New Instruments and Techniques for Ultrasonic Measurement of Tank Ship Corrosion Losses.561t

## F

- Fiebach, Seymour J.**  
Discussion—Performance of Organic Coatings in Tropical Environments....643t
- Fincher, D. R.**  
Corrosion Problems Associated With Sour Gas Condensate Production.....413t
- Firestone, John Tom**  
Discussion—New Bonding Process Gives Added Versatility to Cladding....10-90
- Fisher, A. O.**  
Laboratory Methods for Determining Corrosion Rates Under Heat Flux Conditions, with F. L. Whitney, Jr.....257t
- Floyd, G. L.**  
See Engle, J. P.....69t
- Fontana, M. G.**  
See Greene, N. D.....25t  
See Greene, N. D.....39t  
See Staehle, R. W.....373t
- Forgeson, B. W.**  
See Alexander, A. L.....291t
- Foster, R. S.**  
A Resume of Procedures For Testing and Evaluating Chemical Resistant Coatings and Linings, with V. B. Volkening.....10-85
- Francis, H. T.**  
See Koehler, E. L.....477t
- Fraser, John P.**  
Discussion—Delayed Failure of High Strength Steels.....212t
- Freedman, A. J.**  
Discussion—Corrosion Prevention in Tankers and Storage Tanks by Fogging or Flotation with an Inhibitor Solution.....244t  
Discussion—Corrosion in Sour Water Strippers.....362t

## G

- Gage, D. G.**  
See Barnard, K. N.....581t
- Galloway, Edward E.**  
Filming Amines Control Corrosion in Utility Plant Condensate System.....8-99
- Garner, Cordell**  
High Temperature, High Pressure Testing of Organic Coatings for Oil and Gas Well Tubing..5-121
- Gegner, P. J.**  
Corrosion Resistance of Titanium and Zirconium in Chemical Plant Exposures..341t  
Discussion.....643t
- Gilman, Harry**  
Discussion—New Bonding Process Gives Added Versatility to Cladding....10-90  
Accumulated Residues Attack Chemical Distilling Column.11-99
- Glass, Dean C.**  
Discussion—Methods of Installing Cathodic Protection Anodes for Offshore Structures..12-106
- Gleekman, Lewis W.**  
Discussion—Design and Materials for Reduced Pump Corrosion.476t
- Gleser, Sol M.**  
Discussion—Methods of Testing Characteristics of Polyethylene Jackets for Steel Pipe....6-100  
Discussion—Glass Fiber Reinforcement for Coatings.12-106
- Godard, Hugh P.**  
Discussion—Influence of Service Temperature on the Resistance of Wrought Aluminum-Magnesium Alloys to Corrosion.....61t  
See Azil, P. M.....529t  
Discussion—Observations on the Mechanisms and Kinetics of Aqueous Aluminum Corrosion.....642t  
Rapid Field Measurement of Sub-Surface Corrosion of Aluminum.....9-114

## G—Continued

- Golan, Simcha**  
See Cornet, L.....262t
- Goodman, Barnard**  
New Formulations Give Versatility to Urethane Coatings.4-100
- Gore, Robert T.**  
Behavior of Tin Alloys in Atmospheric Exposures...3-113
- Graham, B. A.**  
Glass Fiber Reinforcement for Coatings.....4-102  
Discussion.....12-106
- Greenhouse, W. D.**  
See McGlasson, R. L.....437t
- Greenblatt, J. H.**  
Behavior of AZ 63 Alloy and Magnesium—1 Percent Manganese Alloy Anodes in Sodium Chloride Electrolyte, with E. Zinck.....76t  
Comparisons of Wagner's Analysis of Cathodic Protection With Operating Data for Ships.....339t  
Discussion.....643t
- Greene, N. D.**  
A Critical Analysis of Pitting Corrosion, with M. G. Fontana.....25t  
An Electrochemical Study of Pitting Corrosion in Stainless Steels (Part 1—Pit Growth), with M. G. Fontana.....32t  
An Electrochemical Study of Pitting Corrosion in Stainless Steels (Part 2—Polarization Measurements), with M. G. Fontana.....39t  
The Classical Potentiostat: Its Application to the Study of Passivity.....369t
- Gribble, Charles G., Jr.**  
Discussion—New Bonding Process Gives Added Versatility to Cladding....10-90
- Groot, C.**  
See Bowen, H. C.....83t  
Discussion—The Corrosion of Zirconium in Hydrochloric Acid at Atmospheric Pressure.....112t
- Gross, William F.**  
Discussion—Wash Primer Development and Characteristics.....313t

## H

- Habib, Emile E.**  
Discussion—Oil Refinery Applications of Thick-Film Synthetic Coatings.....642t
- Hackerman, Norman**  
See Legault, R. A.....517t
- Hadley, R. L.**  
See Smith, H. J.....327t
- Hamstead, A. C.**  
Comparative Corrosion Resistance of 200 and 300 Series Stainless Steels in Chemical Manufacturing Processes, with L. S. Van Delinder.....147t
- Haskell, L. G.**  
See Barusch, M. R.....158t
- Hawley, R. W.**  
See Calkins, K. W.....447t
- Haygood, A. J.**  
Aluminum Cooling Towers and Their Treatment, with J. Dean Minford.....20t
- Henry, R. C.**  
See Thompson, R. B.....321t
- Hochman, H.**  
Deterioration of Wood by Marine Boring Organisms..45t
- Hockridge, Ralph**  
Rubber-Base Transformer Finish for Severe Environments..1-111
- Holsinger, Fred J.**  
See Benes, Richard.....113t
- Hoyt, W. B.**  
High Temperature Metal Deterioration in Atmospheres Containing Carbon-Monoxide and Hydrogen, with R. H. Caughey.....627t

## H—Continued

- Hudson, R. M.**  
Factors Influencing the Rate-of-Pickling Test on Tin-Plate Steel, with G. L. Stragand..135t
- Hugo, J. P.**  
Discussion.....336t
- Hussein, M. Kamal**  
See Khairy, E. M.....63t
- J**
- Jackson, Brian R.**  
Discussion—Corrosion Control Practices in the Wilmington Water Flood Operation..12-102
- Jaech, J. L.**  
See Bowen, H. C.....83t
- James, W. J.**  
See Straumanis, M. E.....286t
- Jansson, Ole G.**  
See Bruckner, W. H.....389t
- Jasek, Albert W.**  
Discussion—Control of Internal Corrosion of Petroleum Products Pipelines with Oil Soluble Inhibitors.....165t
- Jenkins, Vance N.**  
Discussion—Wash Primer Development and Characteristics.....314t
- Johnson, H. T.**  
See Koehler, E. L.....477t
- Johnson, J. E.**  
Duct Anode Development and Experience in Protection of Underground Cables from Corrosion.....423t
- Johnson, Wayne A.**  
Methods of Installing Cathodic Protection Anodes for Offshore Structures, with James T. Condry.....9-112  
Discussion.....12-106
- Jones, C. H.**  
Corrosion Control Practices in the Wilmington Water Flood Operation.....12-99
- Jones, L. W.**  
Discussion—Corrosion Control Practices in the Wilmington Water Flood Operation..12-102
- Jones, David T.**  
Discussion—Duct Anode Development and Experience in Protection of Underground Cables from Corrosion.....423t  
Case Histories of Differential Aeration Corrosion in Underground Telephone Cables..9-116
- K**
- Kato, T. R.**  
See Meyers, F. H., Jr.....168t
- Keeling, Harry J.**  
Corrosion Protection Features of the Hyperion Ocean Outfall.363t
- Keller, Wayne H.**  
Discussion—Corrosion Resistance of Titanium and Zirconium in Chemical Plant Exposures..643t
- Khairy, E. M.**  
An Electrochemical Study of Aluminum and Aluminum Alloys, with M. Kamal Hussein.....63t
- Klement, J. F.**  
Stress Corrosion Crack Paths in Alpha Aluminum Bronze in Ammonia and Steam Atmospheres, with R. E. Maersch and P. A. Tully.....295t
- Knox, John A.**  
Simple Screening Test for Determination of Inhibitor Film Persistence, with Roy Stout.....554t
- Knuckey, P. J.**  
See Ride, R. N.....251t
- Koehler, E. L.**  
Corrosion Processes in Carbonated Beverage Cans, with J. J. Daly, Jr., H. T. Francis, and H. T. Johnson.....477t

**K—Continued**

Koehler, J. Franklin  
Controlling Internal Corrosion  
of Tank Ships.....557t

Kronstein, Max  
Methods for Investigating the  
Characteristics of Reactive  
Coatings.....508t

Krulfeld, M.  
Corrosion Rate Measurement  
by Hydrogen Effusion in  
Dynamic Aqueous Systems at  
Elevated Temperature and  
Pressure, with M. C. Bloom  
and R. E. Seebold.....179t

Kuhn, W. E.  
The Corrosion of Zirconium in  
Hydrochloric Acid at  
Atmospheric Pressure.....103t

Kulman, Frank E.  
Discussion—Cathodic Protection  
of Lead Cable Sheath.....645t

**L**

Landers, J. E.  
Discussion—Mechanical  
Properties and Corrosion  
Resistance of Oil Well  
Tubing.....53t

Lang, F. S.  
See Copson, H. R.....194t

Larrabee, C. P.  
Mechanisms by Which Ferrous  
Metals Corrode in the  
Atmosphere.....526t

Law, R. J.  
Discussion—Design and  
Materials for Reduced  
Pump Corrosion.....476t

Legault, R. A.  
Corrosion Inhibitor Evaluation  
from Cathodic Polarization  
Measurements, with  
Norman Hackerman.....517t

Leidheiser, Henry, Jr.  
See Buck, Roger III.....566t

Lemmon, J. C.  
Analysis of Industrial Roof  
Construction and Maintenance,  
with W. G. Craig.....513t

Lewis, D. A.  
Corrosion of Reinforcing Steel  
in Concrete in Marine  
Atmospheres.....382t

Logan, Hugh L.  
Corrosion of Type 310 Stainless  
Steel by Synthetic Fuel  
Oil Ash.....443t  
Mechanism of Stress  
Corrosion Cracking.....7-106

Long, Austin K.  
Discussion—Wash Primer  
Development and  
Characteristics.....314t  
Discussion—Oil Refinery  
Applications of Thick-Film  
Synthetic Coatings.....642t  
Discussion—Glass Fiber  
Reinforcement for Coatings.....12-106

Louk, A. V.  
Discussion—Corrosion Control  
Practices in the Wilmington  
Water Flood Operation.....12-102

**M**

MacEwan, J. U.  
Corrosion of Steel Weldments,  
with H. H. Yates.....2t

MacLennan, D. F.  
Impedance Characteristics of  
Isolated Aluminum Oxide  
Films.....283t  
Discussions.....643t

MacQueen, R. B.  
See Maier, R. W.....171t

McDaniel, H. M.  
Methods of Testing Character-  
istics of Polyethylene Jackets  
for Steel Pipe.....6-100

McFarland, R.  
Discussion—The Corrosion of  
Zirconium in Hydrochloric Acid  
at Atmospheric Pressure.....112t  
Discussion—Design and Materials  
for Reduced Pump Corrosion 476t

**M—Continued**

McGlasson, R. L.  
Discussion—Mechanical  
Properties and Corrosion  
Resistance of Oil  
Well Tubing.....53t  
Stress Corrosion Cracking of Oil  
Country Tubular Goods, with  
W. D. Greathouse.....437t  
Discussion.....646t

McIntosh, R. B.  
Corrosion Experience Associated  
With Hydrometallurgical  
Refining of Nickel at  
Sheritt Gordon Mines.....547t

Maersch, R. E.  
See Klement, J. F.....295t

Maier, R. W.  
Oil Refinery Applications of  
Thick-Film Synthetic Coatings,  
with W. E. Cook and  
R. B. MacQueen.....171t  
Discussion.....642t

Martin, J. B.  
See Miller, C. S.....11-108

Mason, David M.  
See Rittenhouse, John B.....245t

Mason, J. F., Jr.  
Minimum Corrosion for Butane  
Isomerization Units—A  
Contribution to the Work of  
NACE Group Committee T-8  
on Refining Industry Corrosion,  
with C. M. Schillmoller  
Publication 59-11.....185t  
Corrosion in Sour Water  
Strippers.....358t

Mears, R. B.  
Discussion—Cathodic Protection  
of Lead Cable Sheath.....644t

Meyer, F. H., Jr.  
Corrosion Problems Associated  
with Uranium Refining, with  
F. J. Podlipiec and  
T. R. Kato.....168t

Meyer, Robert H.  
Corrosion Inhibitor Testing  
Inside a Products Pipe Line.....131t

Myles, K. M.  
See Bruckner, W. H.....591t

Mikhailovsky, Y. N.  
See Tomashov, N. D.....77t

Miller, C. S.  
Some Properties and Uses of  
Chlorinated Polyether, with  
J. B. Martin.....11-108

Miller, D. N.  
Whole System Installed in  
Nine Months—Cathodic  
Protection of Southern  
Pacific's High-Pressure  
Products Pipe Line.....12-104

Minford, J. Dean  
See Haygood, A. J.....20t

Moore, K. L.  
Discussion—Corrosion Prevention  
in Tankers and Storage Tanks  
by Fogging or Flotation with  
An Inhibitor Solution.....244t

Morgan, Albert R., Jr.  
Corrosion of Types 316 and 317  
Stainless Steel by 75 Percent  
and 85 Percent Phosphoric  
Acid.....351t  
Discussion.....644t

Morgan, John H.  
Internal Cathodic Protection of  
Large Steel Pipes Carrying  
Sea Water.....417t

Morley, Harland A.  
Improved Methods Plus Hot  
Spray Speed Application of  
Saran Coatings.....3-116

Morrison, A. V.  
Discussion—Design and  
Materials for Reduced  
Pump Corrosion.....476t

Mueller, E. R.  
See Edwards, K. N.....275t

Muir, Parke Denton  
Discussion—Simple Screening  
Test for Determination of  
Inhibitor Film Persistence.....566t

Mullarkey, E. J.  
Applications of Lead-Acid Brick  
Systems in Chemical Plants.....2-98

**M—Continued**

Munger, C. G.  
Comparative Effectiveness of  
Coatings for Offshore Drilling  
Structures.....5-131  
Industrial Coating Performance  
Improved by Good Design.....6-102

Murray, R. G.  
Four-Tower Water Treatment  
Test Facility, with  
M. E. Tester.....492t

**N**

Neidhard, Richard D.  
Discussion—Filming Amines  
Control Corrosion in Utility  
Plant Condensate System.....8-103

Neiman, A. S.  
See Straumanis, M. E.....286t

Nel, L. G.  
Discussion.....336t

Newman, T. R.  
See Bregman, J. I.....97t  
A Laboratory Method for  
Evaluating Corrosion Inhibitors  
for Secondary Recovery.....307t

Noble, H. G.  
See Brown, Roy W.....10-92

Norris, R. S.  
Solving Some Oil Ash  
Corrosion Problems.....5-126

Nowacki, L. J.  
See Edwards, K. N.....275t

Nowak, S. K.  
Discussion—Influence of Service  
Temperature on the Resistance  
of Wrought-Aluminum-  
Magnesium Alloys to  
Corrosion.....337t

**O**

Onakes, Ed W.  
Discussion—Planning A Main-  
tenance Coating Program for A  
Pulp and Paper Plant.....491t

Oosterhout, J. C. D.  
Corrosion Prevention in Tankers  
and Storage Tanks by Fogging  
or Flotation with an Inhibitor  
Solution, with M. E. Stanley  
and W. S. Quimby.....241t

**P**

Palmer, Warren D.  
Discussion—Coatings for Under-  
water Metal Surfaces in  
Fresh Water Exposures.....335t  
Discussion—Some Corrosion  
Problems of Tank Trucks  
and Their Solutions.....2-96

Panter, George  
Discussion—Observations on the  
Mechanisms and Kinetics of  
Aqueous Aluminum Corrosion.....336t

Park, W. R. R.  
See Bobalek, E. G.....202t

Parker, Ivy M.  
Discussion—Control of Internal  
Corrosion of Petroleum  
Products Pipelines with Oil  
Soluble Inhibitors.....165t

Partridge, E. G.  
Use of Plastics and Synthetic  
Elastomers for Underground  
Coatings.....7-101

Patterson, Dean  
Offshore Platform Shows Corro-  
sion Rate of Carbon Steel in  
Gulf of Mexico Exposure.....8-103

Penbody, A. W.  
Use of Magnesium for Cathodic  
Protection of Pipe Lines in  
High Resistivity Soil.....497t

Peckner, D.  
Erosion of Materials by  
Cavitation Attack.....269t

Pedlow, J. Watson  
Recent Developments in  
Applying Polyvinylchloride  
Plastisols.....8-107

Pemberton, George M.  
Evaluating the Economy of  
Reconditioning and Coating  
Underground Steel Pipe.....279t

**P—Continued**

Peterson, M. H.  
Principles and Criteria for  
Cathodic Protection of Steel  
in Sea Water—A Review.....483t  
See Waldron, L. J.....2-87

Phelps, E. H.  
Discussion—Mechanism of Stress  
Corrosion of Austenitic  
Stainless Steels in Chloride  
Waters.....381t

Phillips, J. H.  
Evaluation of Performance of  
Screening Tests of Inhibitors  
to Prevent Chloride Stress Cor-  
rosion, with W. J. Singley.....450t

Piccardo, Jack E.  
Design and Materials for  
Reduced Pump Corrosion.....473t

Piehl, R. L.  
See Barusch, M. R.....158t

Piereson, Russell E.  
See Benes, Richard.....113t

Pike, Vernon B.  
Discussion—Cathodic Protection  
of Lead Cable Sheath.....645t

Podlipiec, F. J.  
See Meyers, F. H., Jr.....168t

Pokorny, J. J.  
Discussion—Cathodic Protection  
of Lead Cable Sheath.....645t

Prange, F. A.  
Mechanical Properties and  
Corrosion Resistance of  
Oil Well Tubing.....49t  
Corrosion in a Hydrocarbon  
Conversion System.....619t

Prather, W. J.  
Coatings Engineers Help In  
Power Plant Planning.....7-107

Preiser, H. S.  
Some Platinum Anode Designs  
for Cathodic Protection of  
Active Ships, with  
B. H. Tytell.....596t

Prior, J. E.  
Corrosion of Valve Seat Ring  
Results in Flexible Metal.... 1t

Puckett, George J.  
Discussion—The Corrosion of  
Zirconium in Hydrochloric Acid  
at Atmospheric Pressure.....112t

**Q**

Quimby, W. S.  
See Oosterhout, J. C. D.....241t

**R**

Radavich, John F.  
Effect of Silicon on High  
Temperature Oxidation of  
Stainless Steels.....613t

Rajagopalan, K. S.  
Corrosion of Metals at  
Mandapam Camp, India, with  
M. Sundaram and  
P. L. Annamalai.....631t

Rench, Joe E.  
Discussion—Wash Primer  
Development and  
Characteristics.....314t

Renshaw, W. G.  
Discussion—Comparative  
Corrosion Resistance of 200  
and 300 Series Stainless Steels  
in Chemical Manufacturing  
Processes.....156t

Ride, R. N.  
Photoelectric Information  
Selector, with  
P. J. Knuckey.....251t

Rittenhouse, John B.  
Study of Chemical Factors  
Affecting Corrosion of Carbon  
Steel AISI 1020 by Liquid-  
Phase Fuming Nitric Acid,  
with David M. Mason.....245t

Robinson, J. L.  
Discussion—Behavior of AZ 63  
Alloy and Magnesium—1 Per-  
cent Manganese Alloy Anodes  
in Sodium Chloride  
Electrolyte.....643t

Rockwell, W. C.  
Material Selection in Chemical  
Milling Process.....8-105

## R—Continued

- Rogers, T. H.**  
Uses and Abuses of Aluminum in  
Wooden-Hulled, Aluminum-  
Frame Minesweepers, with  
W. K. Chinn.....403t
- Roller, David**  
Effect of Molten Boron Oxide on  
Selected High Temperature  
Alloys, with C. R. Andrews. 85t
- Rosene, R. B.**  
See Engle, J. P.....69t
- Roth, Stanley**  
Discussion—Wash Primer  
Development and  
Characteristics .....314t
- Rowe, Leonard C.**  
Automotive Corrosion Resistance  
—Past and Present.....167t
- S**
- Scheil, M. A.**  
Discussion—Mechanical  
Properties and Corrosion  
Resistance of Oil Well  
Tubing .....53t  
Discussion—Comparative  
Corrosion Resistance of 200  
and 300 Series Stainless Steels  
in Chemical Manufacturing  
Processes .....157t  
Discussion—Corrosion  
Problems Associated with  
Uranium Refining .....170t
- Schillmoller, C. M.**  
See Mason, J. F., Jr.....185t  
See Mason, J. F., Jr.....358t  
Discussion—Corrosion of Types  
316 and 317 Stainless Steel by  
75 Percent and 85 Percent  
Phosphoric Acid .....644t
- Schuhmacher, Gordon S.**  
Discussion—Corrosion Control  
Practices in the Wilmington  
Water Flood Operation...12-102
- Schwogler, E. J.**  
The Evaluation of Certain  
Organic Nitrogen Compounds  
as Corrosion Inhibitors, with  
L. U. Berman.....128t
- Scott, Willard R.**  
Discussion—Corrosion Control  
Practices in the Wilmington  
Water Flood Operation...12-102
- Seebold, R. E.**  
See Krulfeld, M.....179t  
Visual Observations on the  
Water Stream In an Elevated  
Temperature High Velocity  
Loop .....183t
- Segraves, William B.**  
Discussion—Corrosion in a  
Hydrocarbon Conversion  
System .....621t
- Severance, W. A.**  
Discussion—Wash Primer  
Development and  
Characteristics .....314t
- Shannon, Donald W.**  
Factors Affecting the Corrosion  
of Steel by Oil-Brine-Hydrogen  
Sulfide Mixtures, with  
James E. Boggs.....299t  
An Analytical Procedure for  
Testing the Effectiveness of  
Hydrogen Sulfide Corrosion  
Inhibitors, with  
James E. Boggs.....303t

## S—Continued

- Shaw, Homer L.**  
Discussion—Filming Amines  
Control Corrosion in Utility  
Plant Condensate System...8-103
- Shields, Hobart**  
Selecting Corrosion and Scale  
Inhibitors for Cooling Water,  
with L. V. Sorg and  
R. L. Stutz.....233t
- Shumaker, M. Byron**  
See Dix, E. H., Jr.....55t  
Discussion .....338t
- Simons, C. S.**  
Materials Selection and Design  
Problems in a Nickel-Cobalt  
Extraction Plant .....4-95
- Singley, W. J.**  
See Phillips, J. H.....450t
- Sjoberg, J. W.**  
See Backensto, E. B.....125t
- Sloope, Billy W.**  
See Buck, Roger III.....566t
- Slunder, C. J.**  
The Residual Oil Ash Corrosion  
Problem—A Review .....601t
- Smith, G. B.**  
Equipment and Procedure for  
the Evaluation of Stress  
Corrosion Susceptibility of a  
Wrought Copper Base Alloy.101t
- Smith, H. J.**  
Corrosion of Die Casting Alloys  
in Detergent Solutions  
Measured by Electrical  
Resistance Method, with  
R. L. Hadley.....327t
- Sorg, L. V.**  
See Shields, Hobart.....233t
- Southwell, C. R.**  
See Alexander, A. L.....291t
- Spalding, James C., Jr.**  
Discussion—High Temperature,  
High Pressure Testing of  
Organic Coatings for Oil and  
Gas Well Tubing.....5-124
- Staehle, R. W.**  
Mechanism of Stress Corrosion  
of Austenitic Stainless Steels  
in Chloride Waters, with F. H.  
Beck and M. G. Fontana...373t
- Stanbury, Charles M.**  
Discussion—Oil Refinery  
Applications of Thick-Film  
Synthetic Coatings .....642t
- Stanley, M. E.**  
See Oosterhout, J. C. D.....241t
- Stedman, R. F.**  
See Thompson, R. B.....321t
- Stern, Milton**  
Discussion—Corrosion Resistance  
of Titanium and Zirconium in  
Chemical Plant Exposures.644t
- Stout, Roy**  
See Knox, John A.....554t
- Stragand, G. L.**  
See Hudson, R. M.....135t
- Stratfull, R. F.**  
Progress Report on Inhibiting  
the Corrosion of Steel in a  
Reinforced Concrete Bridge.331t

## S—Continued

- Straumanis, M. E.**  
Rates of Dissolution and  
Passivation of Hafnium-Free  
Zirconium in Hydrofluoric  
Acid, with W. J. James and  
A. S. Neiman.....286t
- Stutz, R. L.**  
See Shields, Hobart.....233t
- Sudrablin, L. P.**  
Discussion—Development of the  
Redox Probe Field  
Technique .....335t
- Suman, Robert P.**  
Discussion—High Temperature,  
High Pressure Testing of  
Organic Coatings for Oil and  
Gas Well Tubing.....5-124
- Sundaram, M.**  
See Rajagopalan, K. S.....631t
- Szymanski, Walter A.**  
Recovery of Graphitically  
Embrittled Nickel .....1-112
- T**
- Tester, M. E.**  
See Murray, R. G.....492t
- Thompson, D. H.**  
Probability as Related to Stress  
Corrosion Cracking of  
Copper Alloys .....433t
- Thompson, R. B.**  
Evaluation of Organic Corrosion  
Inhibitors for Special Applica-  
tions in Petroleum Refining,  
with R. F. Stedman, Charles  
Wankat and R. C. Henry...321t  
Discussion—Corrosion in Sour  
Water Strippers .....362t
- Tomashov, N. D.**  
Corrosivity of Soil, with  
Y. N. Mikhailovsky.....77t
- Tonetti, Serge (Lt. Col.)**  
Discussion—Planning a Main-  
tenance Coating Program for a  
Pulp and Paper Plant.....491t
- Troiano, Alexander R.**  
Delayed Failure of High  
Strength Steels .....207t
- Troutner, V. H.**  
High Temperature Corrosion  
Product Films on Aluminum. 7t  
Observations on the Mechanisms  
and Kinetics of Aqueous  
Aluminum Corrosion (Part 1—  
Role of the Corrosion Product  
Film in the Uniform Aqueous  
Corrosion of Aluminum)....9t
- Tully, P. A.**  
See Klement, J. F.....295t
- Tytell, B. H.**  
See Preiser, H. S.....596t
- V**
- Van Delinder, L. S.**  
See Hamstead, A. C.....147t
- Van Orlen, Jerold Miles**  
Discussion—Delayed Failure of  
High Strength Steels.....212t
- Vollmer, L. W.**  
Discussion—Influence of  
Temperature on Corrosion  
Fatigue .....268t
- Vore, Herbert G.**  
Discussion—New Bonding  
Process Gives Added  
Versatility to Cladding....10-90

## V—Continued

- Volkering, V. B.**  
See Ballard, D. A.....503t  
See Foster, R. S.....10-85
- W**
- Waldron, L. J.**  
Experimental Studies of Cathodic  
Protection for Naval Vessels,  
with M. H. Peterson and  
M. C. Bloom.....2-87
- Wallace, A. J.**  
See Bennett, G. A.....587t
- Wallace, E. W.**  
Discussion—Corrosion Control  
Practices in the Wilmington  
Water Flood Operation...12-102
- Wankat, Charles**  
See Thompson, R. B.....321t
- Warren, Donald**  
The Effect of Sigma Phase vs  
Chromium Carbides on the  
Intergranular Corrosion of  
Type 316 and 316L Stainless  
Steel (Part 1—A Survey of  
the Literature) .....213t  
The Effect of Sigma Phase vs  
Chromium Carbides on the  
Intergranular Corrosion of  
Type 316 and 316L Stainless  
Steel (Part 2—Laboratory  
Investigation) .....221t
- Wells, E. R.**  
Characteristic Properties of  
Polyurethane Protective  
Coatings .....12-93
- Wells, Harold C.**  
Discussion—Wash Primer  
Development and  
Characteristics .....313t
- Whiting, L. R.**  
Wash Primer Development  
and Characteristics .....311t
- Whitney, F. L., Jr.**  
See Fisher, A. O.....257t
- Wilson, W. L.**  
See Gegner, P. J.....341t  
Discussion—Potentialities and  
Applications of Special Corro-  
sion Resistant Refractories.10-98
- Woodward, W. Searle**  
Uses for Varistors With Direct  
Current Corrosion Meters...68t
- Wright, Charles C.**  
A Field Method for Screening  
Inhibitors for Prevention of  
Water Flood Corrosion....7-97
- Wright, Kenneth E.**  
Discussion—Wash Primer  
Development and  
Characteristics .....314t
- Wylie, R. D.**  
See Eberle, F.....622t
- Y**
- Yates, H. H.**  
See MacEwan, J. U.....2t
- Yocom, John E.**  
Deterioration of Materials in  
Polluted Atmospheres .....541t
- Z**
- Zinck, E.**  
See Greenblatt, J. H.....76t



ol. 15

.503t  
10-85

die

2-87

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